EXHIBIT 41

UNITED STATES DISTRICT COURT
District of South Carolina
Greenville Division

Beatrice Torres Dennis, *et al.*, Plaintiffs, v. City of Greenville, *et al.*, Defendants.	No. 6:12-cv-1767 JMC

DECLARATION OF MARK KROLL, PhD, FACC, FHRS

I, Mark Kroll, being of legal age and under the penalties of perjury, state as follows:

1. I am a competent adult and have personal knowledge of the following facts, or believe them to be true based on information and belief. Facts about which I do not have personal knowledge are of the type reasonably relied upon by experts in this field and have probative value to me in rendering my opinions.

2. Attached hereto is a true and accurate copy of my expert report in this litigation.

3. The report summarizes my analysis and findings and includes a statement of my opinions. The report also includes data and other information considered by me in forming my opinions and sets out my qualifications (including my resume).

4. My opinions are expressed to a reasonable, or higher, degree of professional certainty.

5. I affirm under the penalties of perjury that the foregoing statements are true and correct.

Mark Kroll, PhD, FACC, FHRS 27 Jul 2013

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Abstract of Case

On 9 August 2010, Mr. Andrew Torres resisted officers attempting to transport him for mental health treatment and he received probe-mode applications from an X26 CEW (Conducted Electrical Weapon) deployed to his left arm by Off. Koepke. An M26 deployment by Off. Hill was unsuccessful as only a single probe landed while the other missed. Mr. Torres may also have received drive-mode applications to his back from an M26 CEW.

Several minutes after the last CEW applications, Mr. Torres was finally handcuffed. He then occasionally still resisted by attempting to lift his torso off of the ground. Over 20 minutes after the CEW applications, Mr. Torres was noted to be cyanotic and paramedics (already on their way) were by his side within about 1 minute. Tragically, Mr. Torres could not be resuscitated in spite of this prompt care.

Summary of Case Specific Opinions

The probe-mode application of the TASER® CEW represented what has been proven to be the safest method of controlling and facilitating restraint of a resistant subject. The uses of the CEWs played no causal or contributory role in the tragic cardiac arrest of Mr. Andrew Torres (Mr. Torres) on 9 August 2010. The CEWs can be scientifically eliminated as playing any causal role in Mr. Torres' death for the following reasons:

1. Mr. Torres did not have the cardiac arrest rhythm of VF (ventricular fibrillation). VF is the cardiac arrhythmia expected with electrocution from electrical stimulation and thus the CEWs had nothing to do with Mr. Torres' cardiac arrest. [1-10]

2. Mr. Torres was able to resist and talk long after the CEW applications. Had the CEW induced a cardiac arrest, this would have been immediately impossible. With VF, the blood pressure collapses within 3 seconds and any ability to do anything volitional is gone.[11] Talking ceases typically within 13 seconds.[12] If someone is standing then the collapse occurs within 1-5 seconds.[13]

3. Mr. Torres' loss of breathing did not occur until about 25 minutes after the CEW applications. Had the CEWs been able to induce a cardiac arrest, Mr. Torres' breathing would have ceased within 12-60 seconds.[14, 15]

4. Mr. Torres' cyanosis did not occur until about 24 minutes after the CEW applications.

5. No CEW probe landed near the heart of Mr. Torres.

6. Mr. Torres (73 inches in length and 230 pounds) had a BMI (body-mass-index) of 30.4 kg/m^2 putting him just into the obese category. With that BMI — even assuming *arguendo* that a CEW probe fully embedded directly over his heart — there was no chance of cardiac effects. I.e. the closest CEW contact was far too distant from Mr. Torres' heart to even arguably raise the possibility of electrocution by the CEW.

7. The CEWs deliver a safe level of current as specified by the UL (Underwriters Laboratory) Electric Fence standards.[16] In fact, they satisfy all relevant electrical safety standards. Thus, there was no risk of an CEW-induced cardiac arrest. (The theoretically possible exception applies only to an extremely thin person with a penetrating probe perforating all of the skeletal the overlaying muscle layers and nearly touching the heart. That did not occur in this case.)

8. TASER CEWs deliver less current than some U.S. (United States) FDA (Food and Drug Administration) approved models of TENS (Transcutaneous Electronic Nerve Stimulator) pain-blocking units. Thus, even if the CEW electrodes had contacted Mr. Torres' body in close proximity to the sensitive areas of his heart, which they did not, there was no risk of a cardiac arrest.

Timelines

Table 1. Koepke X26 Time Correction

Closest Clock Check	11-Aug-10		
Previous Clock Correction	3-Nov-09		
Shown Time	15:46:57		
Actual Time	15:39:29		
Elapsed Days	281		
Drift (min:sec)	0:07:28	Positive = "fast"	
Seconds of Drift	448		
Drift Rate: Seconds per Day	1.59		
Date of Incident	9-Aug-10		
Closest Clock Correction	11-Aug-10		
Days Elapsed from Correction	-2		
Predicted Seconds of Drift	-3.2		
Predicted Drift (min:sec)	-0:00:03		
Total Correction	0:07:25		
Raw Time of Last Trigger Pull	16:43:36	Local	
Actual Time of Last Trigger Pull	16:36:11	Local	End
Raw Time of First Trigger Pull	16:42:30	Local	Start
Actual Time of First Trigger Pull	16:35:05	Local	Start
Recall that X26 raw time reflects the END of the trigger pull			

Table 2. Koepke X26 Trigger Pulls

Trigger Pull	Raw End Time	Duration	Corrected Start	Corrected End	Gap
1	16:42:35	0:00:05	16:35:05	16:35:10	
2	16:42:41	0:00:05	16:35:11	16:35:16	0:00:01
3	16:42:47	0:00:05	16:35:17	16:35:22	0:00:01
4	16:42:54	0:00:05	16:35:24	16:35:29	0:00:02
5	16:43:03	0:00:05	16:35:33	16:35:38	0:00:04
6	16:43:16	0:00:05	16:35:46	16:35:51	0:00:08
7	16:43:30	0:00:05	16:36:00	16:36:05	0:00:09
8	16:43:36	0:00:05	16:36:06	16:36:11	0:00:01
		0:00:40			
Time offset	0:07:25				

Table 3. Hill M26 Trigger Pulls

Trigger Pull	Raw Time	Est Duration	Corrected Start	Corrected Est End	Gap
1	16:32:39	0:00:05	16:35:15	16:35:20	
2	16:32:45	0:00:05	16:35:21	16:35:26	0:00:01
3	16:32:53	0:00:05	16:35:29	16:35:34	0:00:03
4	16:33:02	0:00:05	16:35:38	16:35:43	0:00:04
5	16:33:08	0:00:05	16:35:44	16:35:49	0:00:01
6	16:33:13	0:00:01	16:35:49	16:35:50	0:00:00
7	16:33:14	0:00:05	16:35:50	16:35:55	0:00:00
8	16:33:21	0:00:05	16:35:57	16:36:02	0:00:02
9	16:33:34	0:00:05	16:36:10	16:36:15	0:00:08
Koepke corrected start	16:35:05				
Delay to Hill	0:00:10				
Pred. Hill 1st pull start	16:35:15				
Hill raw 1st pull end time	16:32:39				
Total offset for Hill	0:02:36				
Recall that the M26 raw time reflects the START of the trigger pull					

Table 4. Sgt. Tarkenton Photo Timeline

Sequence	Serial Number	Raw Time	Corrected Time	Depicts
1	100_0211	16:56:00	16:51:30	Torres handcuffed & prone
2	100_0212	16:57:00	16:52:30	Probe in left biceps
3	100_0213	17:02:00	16:57:30	Handcuffed left wrist
4	100_0214	17:03:00	16:58:30	Handcuffed right wrist
	Time correction	0:04:30		

Time correction is estimated from the following factors:

1. Tarkenton required 2 minutes to get to room and remove camera
    a. Suggests camera was < 7 minutes fast
2. Camera is presently 2 minutes fast
    a. Camera was 2 ± 3 minutes fast including rounding and drift
3. Last photo was taken before cardiac arrest was noted
    a. Suggests camera was > 3:47 minutes fast

Table 5. Overall Incident Timeline

Time	Item	Source	Time from CEW Start	Time from Cardiac Arrest
16:29:07	Hill, Keopke on scene	Dispatch transcript		
16:30:11	Dirton on scene	Dispatch transcript		
16:35:05	Start of Koepke 1st trigger pull	X26 download		
16:35:45	Start of Hill 1st trigger pull	*Assumes 10 s delay to Hill*	0:00:40	
16:36:11	End of Koepke trigger pulls	X26 download	0:01:06	
16:36:15	*End of Hill trigger pulls*	*30-second span*	0:01:10	
16:37:45	Sgt. Tarkenton requested	Dispatch transcript	0:02:40	
16:38:20	Koepke request radio traffic hold	Dispatch transcript	0:03:15	
16:38:22	Male scream	Dispatch transcript	0:03:17	
16:45:00	Dean on scene.	GPD incident recall.*	0:09:55	
16:45:23	Torres handcuffed	Dispatch transcript	0:10:18	
16:47:00	Tarkenton on scene	GPD incident recall	0:11:55	
16:47:00	Johnson arrived	Johnson report**	0:11:55	
16:47:05	Dean requested EMS for cuts and scratches	Dispatch transcript	0:12:00	
16:47:36	Call received by EMS	EMS Event Record	0:12:31	
16:48:00	Torres was still fighting after Tarkenton & Johnson arrival	Koepke, Johnson, & Tarkenton report	0:12:55	
16:51:30	Tarkenton's 1st photo		0:16:25	
16:58:00	Sgt. Johnson asked to get hobble	Koepke & Hill report	0:22:55	
16:58:30	Tarkenton's 4th (last) photo	7-minute gap from first to last photo.	0:23:25	
16:59:00	Est. time of cardiac arrest		0:23:55	
16:59:13	Torres passed gas and became cyanotic as EMS arrived. EMS was 1.5 blocks away when Torres became cyanotic.	EMS Event Record for arrival. Koepke deposition.	0:24:08	0:00:13
17:00:00	Hill heard breathing, found no wrist pulse, and was looking for carotid pulse when EMS came in the door.	Hill deposition. EMS report for time.	0:24:55	0:01:00
17:02:00	Asystole rhythm	EMS report.	0:26:55	0:03:00

Notes:

* Dean report states he arrived ~16:38. Audio transcript shows he was en route at 16:38:53

* * GPD incident report has Johnson arriving at 17:15 which is clearly erroneous

Details of Case Specific Opinions

1. Mr. Torres' Cardiac Arrest Rhythm Was Asystole.

Mr. Torres' cardiac arrest rhythm was asystole and not VF (ventricular fibrillation). Asystole and PEA (pulseless electrical activity) are the typical non-shockable cardiac arrest rhythms and are not inducible with electrical stimulation. [5-10] Electrically-induced VF will eventually deteriorate into asystole or PEA. Without chest-compressions, this takes over 30 minutes.[17] With CPR, the time for VF to deteriorate to asystole or PEA is even longer — around 60 minutes or more.[18]

Asystole and PEA are the most common cardiac arrest rhythms in deaths associated with drug and alcohol abuse or excited delirium syndrome.[19-26] See Background section "Cardiac Arrest Rhythms" for more details.

Mr. Torres did not have the cardiac arrest rhythm of VF, which eliminates the possibility that he was electrocuted by the CEW applications.

2. Mr. Torres Was Not Thin Enough for the Possibility of CEW Electrocution.

The shortest skin to heart (STH) distance has been determined by echocardiographic and CT (computed tomography) study.[27, 28] This distance is predicted by the BMI (Body-Mass Index) which has to be less than 20-25 kg/m^2 for any concern over the risk of VF induction. Mr. Torres' height of 73 inches and weight of 230 lbs gave him a BMI of 30.4 kg/m^2 (kilograms per meter squared) putting him just into the "obese" category.

The tip of an CEW probe would have to be within 4 mm (millimeters) of the human heart (or within 8 mm of the more sensitive swine heart) in order to theoretically electrically induce a cardiac arrest.[29-31] See Background section "How Close is Close" for more details. Thus, even if a CEW probe had fully penetrated directly over Mr. Torres' heart it would have been far too distant to have even speculatively caused a cardiac arrest by inducing VF.

No electrical current was delivered sufficiently close to Mr. Torres' heart to even arguably affect it because of Mr. Torres' obesity.

3. Mr. Torres May Have Received Some Drive-Stun CEW Applications.

As discussed in Background section "CEW Drive-Stun Mode: Skin Rub vs. Injection" CEW drive-stun applications have no clinically significant physiological or pathological effects. Even small swine cannot be put into cardiac arrest with drive-stuns. [32-35] No published case report has ever suggested that someone had a cardiac arrest with drive-stuns.

Possible drive-stuns had no clinically significant physiological or pathological effects and thus need not be considered further.

4. No CEW Probe Landed Near Mr. Torres' Heart.

Assuming *arguendo* that Mr. Torres was extremely thin, had presented in VF, had not breathed long after the CEW application, then CEW electrocution can still be eliminated by the absence of any CEW probes near the heart. See Background section "How Close is Close" for more details.

No CEW current was delivered near Mr. Torres' heart and thus the CEW could not have affected it — much less electrocuted Mr. Torres.

5. Mr. Torres Was Resisting Well After the CEW Applications.

Mr. Torres was reported struggling when Sgts. Tarkenton and Johnson arrived around 16:47. This is at least 8 minutes after the last CEW applications. With VF, the blood pressure collapses within 3 seconds and consciousness is usually lost within 10 seconds total.[11, 13] With supine patients this takes 13 ± 4 s.[12] See Background section "Loss of Consciousness is Rapid" for more details.

Mr. Torres was resisting long after the last CEW application. This eliminates the possibility of the CEW causing his eventual cardiac arrest i.e. electrocuting him.

6. Mr. Torres Was Breathing Well After the CEW Applications.

Mr. Torres was still breathing around 17:00 when EMS arrived. This is about 24 minutes after the last CEW application. Had the CEW been able to induce a cardiac arrest, Mr. Torres' breathing would have ceased within 12-60 seconds.[14, 15] See Background section "Breathing Cessation is Rapid" for more details.

Mr. Torres was breathing until about 24 minutes after the last CEW application. This eliminates the possibility of the CEW causing his eventual cardiac arrest.

7. Mr. Torres Was Not Cyanotic Well After the CEW Applications.

Mr. Torres had normal lip color in Sgt. Tarkenton's 1st photo taken about 15 ½ minutes after the end of the CEW applications. The central cyanosis (bluish lips due to systemic loss of oxygenation) was not seen until about 23 minutes after the end of the CEW applications. Had the CEW been able to induce a cardiac arrest, the cyanosis would have occurred within 1 or 2 minutes.

Mr. Torres' central cyanosis did not occur until long after the last CEW application. This eliminates the possibility of the CEW causing his eventual cardiac arrest i.e. electrocuting him.

8. How Many Seconds of CEW Probe-mode Current Did Mr. Torres Receive?

The download from Off. Koepke's X26 CEW shows a total of 40 seconds of trigger pulls. This is consistent with the metallurgical analysis of the probes showing 30-40 seconds of current flow.

The evidence suggests that Off. Hill's M26 CEW missed with 1 probe so no current was passed. That is also consistent with the metallurgical analysis of the probes showing no current flow thru his probes. Finally, it is consistent with the lack of effect and also the shocking sensation that Off. Hill received from the wires himself. The only contrary evidence is the Autopsy Report statement that probe wounds were found in the "left upper back and left mid-back." However, no 2nd back probe is found in any of the contemporaneous incident-scene pictures (taken by Sgt. Tarkenton) nor is a 2nd back probe found in the autopsy pictures. The nude autopsy photos also do not appear to show a 2nd probe wound.

It must also be stressed that the CEW current was only passed within the left arm. Animal and human studies of physiological stress (including acidosis) have used probe spreads diagonally across the whole thorax to engage a large muscle mass. Current thru only a left arm would not cause any material physiological stress on the body.

Mr. Torres received 30-40 seconds of CEW probe-mode current and this was confined to his left arm.

Expert Report of Mr. Ernest Burwell

I will not be offering testimony on general police practices or the use of force. However, I reviewed the Expert Report of Mr. Burwell and wish to comment on some of his opinions regarding the TASER CEW application.

On page 5. Mr. Burwell stated:

> The maximum Taser activation a person should receive is 15 seconds and no more than 3 five second applications. Only one Taser should be used. The data port information clearly indicates the Tasers were used far beyond the maximum limits. See Taser, IACP and DOJ recommendations.

There are several errors in this paragraph:

1. There is no scientific support for the speculation that CEW applications must be limited to 3 trigger pulls or 15 seconds. The idea of a 3-application limit is sometimes referred to as the "baseball" rule as that appears to be the source based on a 3-strike limit. See the background section on "Electricity does not build up like poison."
2. Even if there was a scientific basis to an arbitrary time or trigger pull limit it would be irrelevant to this case where the only probe-mode current was delivered to the left arm.
3. The data port information only records trigger pulls and not current delivery from successful connections. Off. Hill's CEW did not deliver any probe-mode current.
4. The TASER Intl company actually does *not* teach any arbitrary time or trigger pull limits.

On pages 6 & 7 Mr. Burwell stated (citing to the 2005 IACP guidelines):

> Limiting the number of energy cycles, the use of continuous cycling of more than 15 seconds, and instances of multiple officer deployments against the same person can help to prevent tetany (muscular spasms) or exhaustion of muscles of respiration and the development of acidosis. Such respiratory impairment, as noted in the previously cited research from British Columbia, "becomes crucial when the [ECW] weapon is used or restraint is applied during or at the end of a prolonged physical struggle." The inability of some subjects to regain free breathing is critical "as the body tries to return to homeostasis and compensate for increased levels of CO2." According to the report, "The state of hypoventilation means that the subject can still breathe, just not at the level their body requires to return to equilibrium.

There are several errors in this paragraph:

1. Mr. Burwell is citing to a 2005 publication that reflected earlier concerns before human studies showed that acidosis is not of concern.
2. The 2010 IACP "Concepts and Issues Paper" on CEWs does not contain the word "acidosis."[36]
3. There is no problem with acidosis in humans. In fact, the use of the CEW reduces acidosis compared to alternative control techniques.[37-40]

On page 9 Mr. Burwell stated:

> Officers Hill and Koepke used multiple Tasers on Andrew Torres which goes against the recommendations of The Department of Justice, The International Association of Chiefs of Police, Greenville Police Department Taser policy, CALEA 41.2.7 Standards for Law Enforcement Agencies, and the use of force policy.

There are errors in this paragraph:

1. The issue of Off. Hill attempting to use his CEW is moot since he missed with a probe and delivered zero current.
2. The present (2010) IACP guidelines state:[36]

> Should multiple devices be employed? If deemed necessary, it is claimed by the manufacturers that the use of a second ECW does not create a dangerous level of cumulative electric current, and may prove beneficial if the initial device is ineffective or malfunctions.

Expert Report of Mr. Melvin Tucker

I will not be offering testimony on general police practices or the use of force. However, I reviewed the Expert Report of Mr. Tucker and wish to comment on some of his opinions regarding the TASER CEW application.

On page 7 Mr. Tucker stated:

> According to Dirton, while he was giving loud commands to Torres to stop resisting, he heard a Taser being cycled.

What Mr. Tucker neglected to state is that a TASER CEW — in normal operation — cannot be heard over loud commands. With a good connection the CEW sound level is about 50 dBA while it jumps up to about 80 dBA when a connection is broken. Hence this cycling was probably that of Off. Hill's trigger pulls with no connection. See Background section subtitled "More is Usually Less."

On page 9 Mr. Tucker stated:

> The newer devices were 50,000-volt, 26-watt systems.

This is incorrect as the M26 CEW delivers 7 watts and the X26 delivers 2 watts.[41]

On page 9 Mr. Tucker also stated:

> Although the medical effects of CEDs (Tasers) continues to be a matter of controversy, there is no question that many people have died shortly after being exposed to CED activations.

Mr. Tucker does not give any citation for his speculation about a contoroversy regarding the medical effects of CEWs as there is very little controversy in the medical and scientific literature. The only thing close to a controversy has been raised in a paper by a Plaintiff's expert, Dr. Zipes, who has suggested that general chest exposures might cause VF.[42] I have published on the risk of a chest exposure where the probe nearly touches the heart in a very skinny person.[43] (Dr. Zipes apparently feels that the danger zone is several centimeters wide.) Since Mr. Torres had no chest probes and did not present in VF, there is no scientific controversy relevant to the possible role of the CEW in his death.

Case Specific Materials Reviewed or Considered

1. Investigative Reports
    a. Radio Traffic Transcript for 2708 Augusta
    b. SLED Investigative File
    c. GPD_GCSO Incident Reports prior to incident
    d. GPD Incident Report for incident
    e. GPD Detailed Incident Recall Printout
    f. Disposition & Incident Reports for Koepke, Hill & Dirton
    g. Amber Allen Supp Report
    h. 2002 Incident at 2708 Augusta St.
    i. Additional GPD Incident Reports re_ protective custody
    j. IA Investigation File
    k. Greenville GFD Hx of Responses to 2708 Augusta St.
2. Post-incident Medical Records
    a. Greenville EMS
    b. Autopsy & Coroner's Report
    c. Miami Brain Analysis
3. Audio Dispatch Recordings
4. Photographs
    a. Sgt. Tarkenton Camera
    b. Photos taken by Forensics
    c. Photos of Officer Involved
5. Depositions
    a. Frank Torres
    b. Rick Torres
    c. Beatriz Torres
    d. Lisa Unkauf
    e. Myrna Torres
    f. Fransisco Torres
    g. Sgt. Tarkenton
    h. Off. Koepke
    i. Pauline Jarrard
    j. Off. Dirton
    k. Off. Dean
    l. Francis Torres
    m. Sgt. Johnson
6. Plaintiff's Expert Reports
    a. Melvin Tucker
    b. Dr. Daniel Spitz
    c. Mr. Ernest Burwell

Exhibits

The exhibits or list of references used as a summary of or support for the information and opinions in this report specifically include each illustration, graphic, chart, and video in this report, referenced in this report, or included in any of the references to this report, as well as any documents, or portions thereof, referenced or cited, or any compilation of documents, are to be considered exhibits to this report and may be utilized as exhibits at deposition and/or trial. These exhibits specifically include, but are not limited to: any document, information, illustration, Microsoft® PowerPoint®, lesson plan, drawing, graphic, video, compilation, etc., that is on, or included in, any of the TASER International, Inc. (TASER) training CDs/DVDs (versions 1 through the current release – which is presently version 18), TASER ECD Research Index, TASER Fact Sheets (TFSs), as well as the TASER[a] Research Compendium, the Arrest-Related Death (ARD) Research Index and Compendium, TASER ECD Field Data and Risk Benefit PowerPoint presentations and Analyses, Volunteer Exposure Reports, spreadsheets, and analyses, Field Use Reports, data, summaries, and appendices, the TASER website (including updates and additions), the www.ecdlaw.info and www.ipicd.com websites, etc. Exhibits also include an ADVANCED TASER M26™ (M26) ECD, TASER X26™ ECD (X26), TASER X2™ ECD, TASER X3™ ECD, fully kitted M26 ECD, fully kitted X26 ECD, fully kitted X2 ECD, fully kitted X3 ECD, TASER cartridges, TASER cartridge wire, TASER probes, a Van de Graff generator, eight (8) AA cells, two (2) three-volt Duracell® CR123 cells, an X26 Digital Power Magazine (DPM, an X26 ECD eXtended Digital Power Magazine (XDPM), stacks of 10,000, 25,000, 50,000, and 100,000 sheets of copy-type paper, vehicle battery jumper cables, 110 V alternating current (AC) electrical cords/cables, ground fault circuit interrupter (GFCI), a can of Pepsi® or other soft drink, an empty soda can, a Nikon® F6 camera, and other exhibits and demonstrative aids.

Electric fence energizers of various brands

Electroconvulsive therapy (ECT) generator

Transcutaneous electronic nerve stimulators (TENS) of various brands

Sound recordings of ECDs played at both normal and slow speed

[a] AIR TASER, M26, X26, X2, and X3 are trademarks of TASER International, Inc. TASER® and ADVANCED TASER® are registered trademarks of TASER International, Inc.

Background:

A. The Electricaphobia Myth

Many people, both lay and professional, have an illogical emotional fear of electricity, *electricaphobia*. From an early age in life it is drilled into young children that 110 V (volt) electrical outlets cause death, Thus, most people have deeply absorbed the urban myths that voltage itself is dangerous and 110 V causes death. While this is scientifically incorrect most people, including most media, hold these myths to be undeniable truths.

Some people subscribe to a myth that since the human body is 97% water and since water transmits electricity that electricity delivered anywhere on the body is carried by the water to the heart and thus causes electrocution. This too is scientifically silly for many reasons. Life itself could not exist without electricity. Just like not all balls are dangerous, so too not all electricity is dangerous. Trying to say that all electricity is dangerous is equivalent to saying that all balls are dangerous. Just like there are marked differences in the effects of being struck by balls including the ping-pong ball, NERF ball, whiffle ball, tennis ball, racquet ball, soft ball, baseball, soccer ball, football, rugby ball, basketball, medicine ball, bowling ball, and wrecking ball. Getting hit with a ping-pong ball is not equivalent to getting hit by a wrecking ball. In this analogy the delivered electrical charge from a CEW is approximately equivalent to a tennis ball while a 110 V wall outlet would be a bowling ball and a high-power transmission line or lightning strike would be a wrecking ball.

B. CEW Probe Mode

In probe mode, the TASER handheld CEW uses compressed nitrogen to fire 2 small probes at typical distances of up to 7.7 m (meters) or 25 feet.[44, 45] (Other TASER cartridge models can reach a distance of 11 m or 35 feet.) When the CEW trigger is pulled, the high voltage first serves to open the nitrogen cartridges to release the nitrogen to propel the probes as directed. These probes themselves are designed to pierce or become lodged in most light clothing (which is usually overcome by the 50,000 V-arcing capability). The sharp portion of the probe is typically 9 mm (millimeters) long and will typically penetrate the epidermis and dermis to a depth of 4-5 mm for a good electrical connection.

Even as a strong static electrical shock will temporarily incapacitate someone, a series of 19 very short duration shocks per second can cause temporary muscle incapacitation. The ultra-short duration electrical pulses applied by TASER CEWs are intended to stimulate Type A-α motor neurons, which are the nerves that control skeletal muscle contraction, but without a high-risk of stimulating cardiac muscle. This typically leads to a loss of regional muscle control and a fall to the ground to end a violent confrontation or suicide attempt.

Small swine 30 kilograms or 65 pounds can occasionally, but rarely, be put into VF when the CEW probes are put within a few mm of the heart and directly across the heart.[46] One study used a custom long plunging probe to deliver the CEW current almost directly (within 6 mm or ¼ inch) to the heart of a pig in order to induce VF.[47] Pigs

are extremely sensitive to electrical currents due to their hearts being literally wired "outside-in" compared to a human's (being wired "inside-out").[48] The swine heart needs 60% less current to go to VF (ventricular fibrillation) comparison to the human heart from external stimulation. I.e. the swine is 2 ½ times as sensitive to electrocution as is the human. This CEW-electrocution effect is also confined to small swine.[49] In stark contrast, human studies consistently show no demonstrated risk of VF with a CEW application.[50-58]

This is clearly the consensus of the scientific and medical community as shown by various position papers. Including, but not limited to: the June 2009 American Medical Association White (Position) Paper concluded:[59]

> Furthermore, no evidence of dysrhythmia or myocardial ischemia is apparent, even when the barbs are positioned on the thorax and cardiac apex.

On May 24, 2011, the National Institute of Justice, after a 5-year study, concluded:[60]

> Current research does not support a substantially increased risk of cardiac arrhythmia in field situations, even if the CED darts strike the front of the chest. There is currently no medical evidence that CEDs pose a significant risk for induced cardiac dysrhythmia in humans when deployed reasonably.

Finally, in June 2012, Bozeman stated:[61]

> "[T]he risk of such dysrhythmias, even in the presence of a transcardiac CEW discharge, is low, and suggest that policies restricting anterior thoracic discharges of CEWs based on cardiac safety concerns are unnecessary."

No danger or harm has been associated with the CEW probe-mode application, in human studies.

C. CEW Drive-Stun Mode: Skin Rub vs. Injection

Alternatively, the CEW may be used in a "drive-stun" mode by pushing the front of the weapon into the skin to function as a higher charge stun gun. With the fixed electrodes only 4 cm (centimeters) or 1.6 inches apart — and the lack of skin penetration — the current flow is primarily through the dermis and fat layer between the electrodes and there is no significant penetration beyond the subdermal (or subcutaneous) fat layer. See Figure 1. Since there is insufficient depth of current flow to capture muscles, the drive-stun mode serves only as a compliance technique.

To make an analogy to medicine, drive-stun is like rubbing an ointment on the skin compared to the probe mode, which is like an injection. They have significantly different effects.

As mentioned above, small swine (30 kg or 65 pounds) can occasionally be put into VF when fully-embedded CEW ***probes*** are nearly touching the heart.[62, 63] *However, it is not possible to fibrillate even small swine with a transcutaneous CEW drive-stun*

application.[32-35] The electrical current simply does not penetrate deeply enough to affect any muscles or organs.

In fact, with a CEW drive-stun application directly over the human phrenic nerves (the nerves that control breathing) there is no effect.[64]

The American Academy of Emergency Medicine (AAEM) has the following guideline on drive-stun applications:[65]

> For patients who have undergone drive stun or touch stun ECD exposure, medical screening should focus on local skin effects at the exposure site, which may include local skin irritation or minor contact burns. This recommendation is based on a literature review in which thousands of volunteers and individuals in police custody have had drive stun ECDs used with no untoward effects beyond local skin effects.

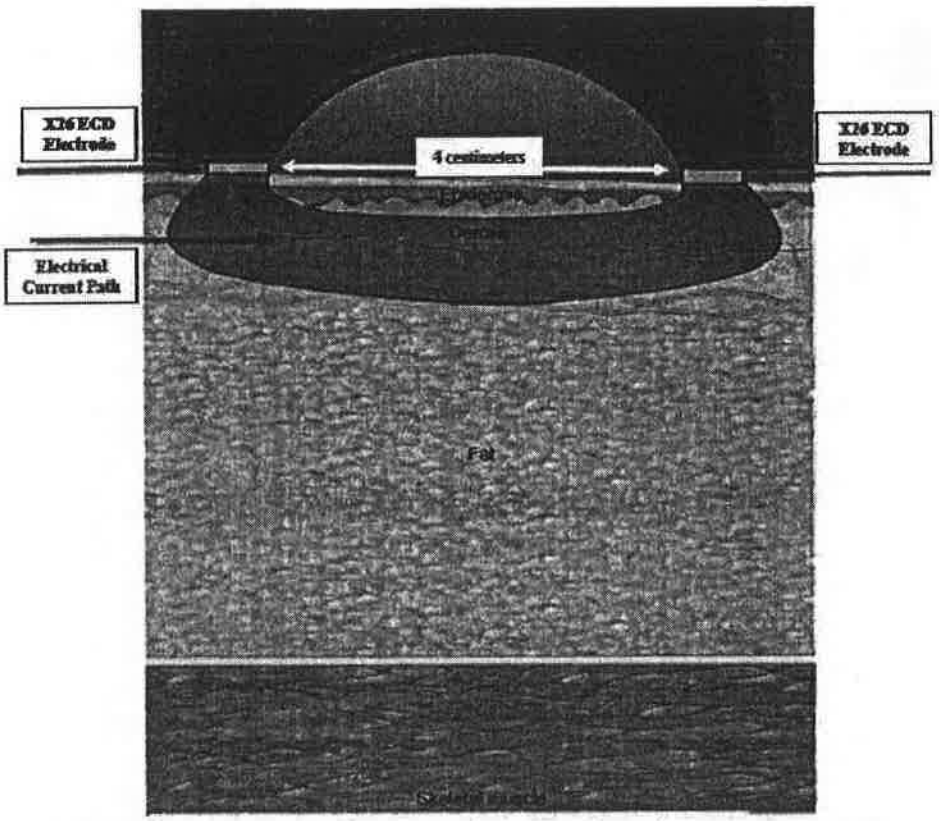

Figure 1. The majority of the drive-stun current is confined to the fat and dermis layer.

The National Institute of Justice, 5-year study of CEWs, found:[60]

> Risk of ventricular dysrhythmias is exceedingly low in the drive-stun mode of CEDs because the density of the current in the tissue is much lower in this mode.

The Federal Court of Appeals for the 9th Circuit [*Brooks v Seattle*], and others, have concluded:

> The [TASER ECD]'s use in "touch" or "drive-stun" ... involves touching the [TASER ECD] to the body and causes temporary, localized pain only. ... this usage was considered a Level 1 tactic, akin to "pain compliance applied through the use of distraction, counter-joint holds, hair control holds, [and pepper spray]" and used to control passively or actively resisting suspects.

CEW drive-stun applications have no clinically significant physiological or pathological effects.

D. Current Flow in the Body

The flow of electrical current in the body is well understood and has been the subject of 100s of scientific papers.[66-76] The simplest analogy is the 1st to 2nd baseline in baseball. See Figure 2. The runners can go directly between the bases but they typically curve out a bit. Similarly, with 2 electrodes in the skin, the current flow "dives" in somewhat just like a runner's path in baseball. The further the electrodes are apart, the deeper the "dive" of the current. This analysis is accurate for a homogenous conductor like saltwater or fat. However, the body's skeletal muscle layer preferable directs current around the outside of the body since electrical current vastly prefers to follow the grain of the muscle instead of going transverse and penetrating into the body.

A runner might deviate somewhat from a straight line but would never run out into the outfield or wander into the bleachers. Similarly, with 2 CEW electrodes on the chest, no current passes into the legs or brain. That would be like a runner going into the outfield and then climbing up into the seats and then back to 2nd base.

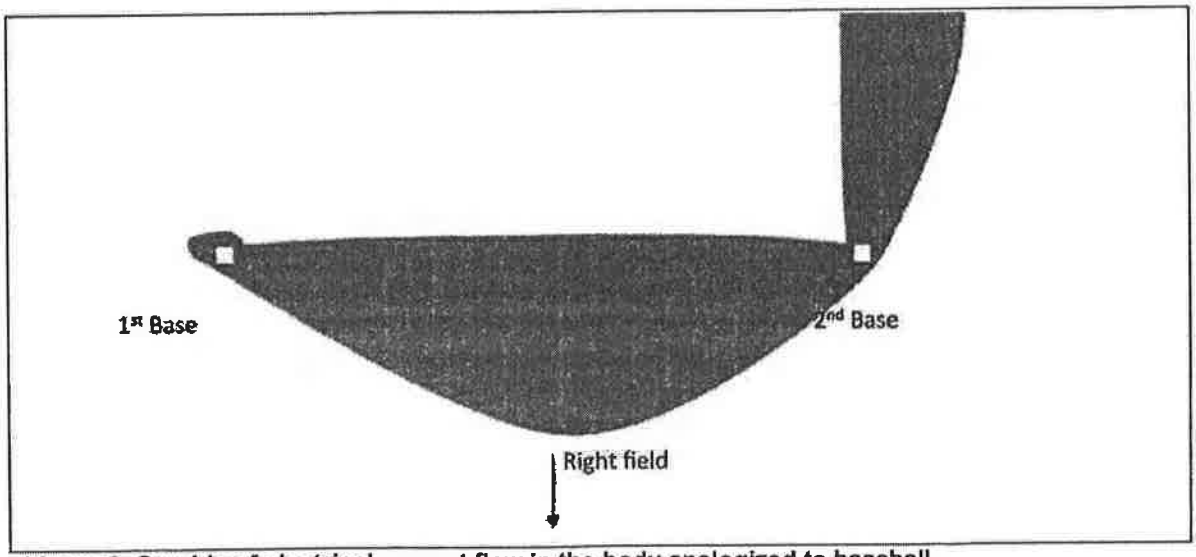

Figure 2. Graphic of electrical current flow in the body analogized to baseball.

E. CEW Comparison to TENS Units

TASER CEWs deliver less current than some models of TENS (Transcutaneous Electronic Nerve Stimulator) units. For example, the popular EMPI® Select™ unit delivers up to 4.5 mA (milliamperes) of aggregate current which is more than the 2.1 mA of the TASER X26 CEW. It is very popular in Europe to use TENS units for treating angina with the electrodes placed across the cardiac silhouette.[77-79] No deaths have been reported.

The X26 CEW delivers less aggregate current than transcutaneous nerve stimulators, which are often used directly across the heart without problems.

F. CEW Comparison to the Electric Fence

It is helpful to discuss the most common and longest existing electronic control device — that controls humans and other mammals by giving short painful electrical stimuli — namely the electric fence.

The IEC (International Electrotechnical Commission), the Au/NZS (Australian/New Zealand Standards). European Norm (EN), British Standards, and UL (Underwriters Laboratories) have long had standards for electric fences.[80, 81] These are the Particular Requirements for Electric Fence Energizers. IEC 60335-2-76, edn 2.1, AU/NZS 60479.1:2010, and the UL Standard for Electric-Fence Controllers in: Laboratories U, ed. UL 69. Independent testing has verified that the TASER X26 CEW satisfies both the IEC, AU/NZS, and UL electric fence standards.[16]

Electric fences normally operate on a pulse rate of 1 PPS (pulse per second). This is because they are primarily designed to stop livestock slowly walking toward them. Obviously this slow pulse rate is insufficient to quickly stop a resisting suspect as they can move too far in 1 second. This is why the X26 CEW operates at a rate at 19 PPS. However the electric fence standards do allow operations at higher pulse rates for a period of up to 3 minutes and have safety standards for those higher pulse rates. (Note that this 3-minute time limit is significantly higher than the total CEW application times alleged in this case.)

The high rate limits are found in section in 23.2.4 of the UL standard 69.[81] It gives a pulse current limit of:

$$I = 20 \cdot T^{-0.7} / \sqrt{PPS}$$

Where I is given in mA of RMS (root-mean-square) current during the very short "on" period of the pulse.

The TASER X26 CEW delivers 0.1 J (joule) per pulse with an inter-barb resistance of 600 Ω (ohms) with a pulse rate of 19 PPS and a pulse width of 100 µs (microseconds). This gives a pulse current of:

$$I_{RMS} = \sqrt{(U/(RT)}$$
$$= \sqrt{(0.1\ J/600\ \Omega \cdot 100\ \mu s)}$$
$$= 1291\ mA$$

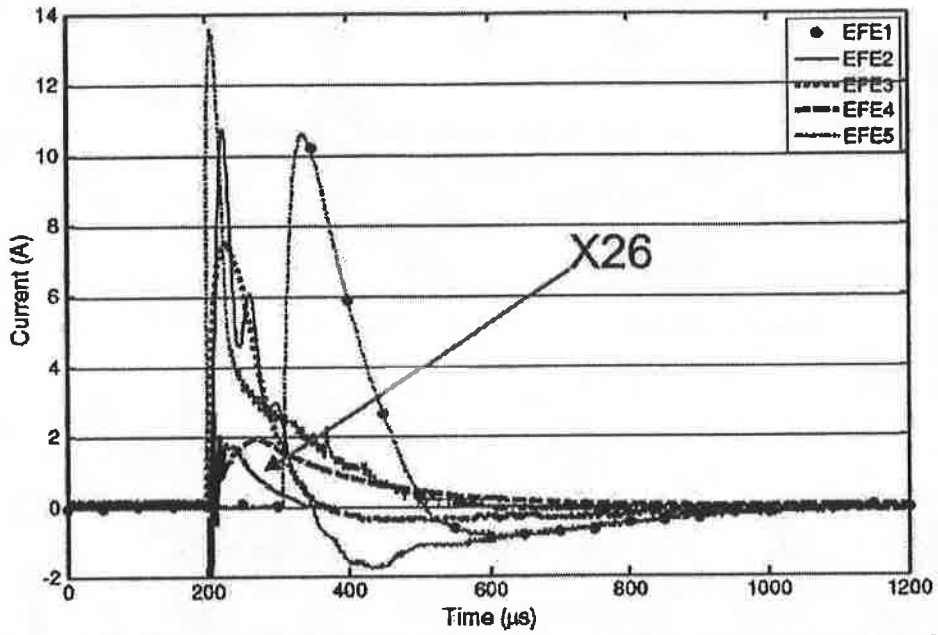

Figure 3. The TASER X26 CEW pulse has less current than commercial electric fence controllers.

The allowed limit is given by:

$$I = 20 \cdot (100\ \mu s)^{-0.7} / \sqrt{PPS}$$
$$= 20 \cdot 630.96 / 4.359\ mA$$
$$= 2894\ mA$$

The electric fence limit is over the X26 CEW output by:

$$Ratio = 2894/1291$$
$$= 2.24$$

Thus the TASER X26 CEW has only 45% of the output allowed by the UL electric fence standard so it can be seen that the X26 CEW satisfies the electric fence standards by a very wide margin.

Another comparison can be made between the outputs of the TASER X26 CEW and the Stafix electric fence energizer shown in Figure 4.

The electric fence standard has evolved from almost 100 years of experience with documented fatalities from earlier high-powered devices. The UL carefully collected data on these units to find out what was a safe limit. The typical accidental exposure to an electric fence is based on someone walking into it and thus is a frontal exposure. Depending upon the relative heights of the fence and the individual this exposure could be anywhere from the face to the thighs and could include skin penetration from barbs on barbed wire. These limits are very stringent and now fatalities from electric

fences are almost unheard of in spite of there being on the order of 100,000 miles of electric fence in the United States alone.

Figure 4. The Stafix M63R electric fence energizer delivers 7 watts with a peak current of 17.2 A.

The TASER X26 CEW satisfies UL electric fence standards by a wide margin and can be thus deemed very safe.

G. Comparison to International Safety Standards

The IEC has set 35 mA as a safe level of utility (50/60 Hz) electrical current for avoiding the risk of VF induction (electrocution).[82] Rapid short pulse stimulation has the same risk of VF induction as does utility power frequencies at a current of 7.4 times higher than the aggregate (or actual or average) current of the rapid pulses. The TASER X26 CEW delivers 19 pulses per second at a charge of about 100 μC (microcoulombs) per pulse.[83] This gives an aggregate current of 1.9 mA which corresponds to a utility power current of 14.1 mA = 1.9 mA • 7.4. This is seen to be less than 1/2 of the IEC VF safety level and thus accepted international standards show that the X26 CEW output cannot electrocute someone.

The TASER X26 CEW satisfies all relevant international electrical safety standards.[84]

H. What is Low-Power Electrocution?

Low-power electrocution is death from an electrical current from a source under 1000 watts.[85] This is contrasted from "high-power" electrocution from power lines or lightning strikes. The death is almost always the result of the electrical current inducing VF. The electrical induction of VF takes a few seconds at most. [1, 11, 86-95] (A massive electrical injury such as a lightning strike can also kill by brain and nerve damage but that is not relevant here.) Since the highest-power TASER CEW (M26) delivers only 7 watts, CEWs fall in the "low-power" category.

In VF, the heart muscle cells continue to contract but at nearly random times. Hence, there is no coordination among the cells and no blood is pumped from the heart. This is called a cardiac arrest. This leads to a collapse within 5-10 seconds as the blood pressure falls rapidly to a level insufficient to maintain consciousness.[11] If someone is

standing then the collapse occurs within 1-5 seconds.[13] Also, the person loses their pulse immediately. Once VF is induced there is no pulse.

Electrocution is a Stand-alone Cause of Death

A final note on electrocution is that it is a stand-alone cause of death. Electrocution is not like a soup recipe where salt and pepper both contribute to the flavor. It does not "contribute" to other causes of death. For example, if someone with late-stage cancer were to receive sufficient current, they would be dead within seconds and the cancer had nothing to do with it. However, if the same person received a lower level of current and died 30 days later, that person was not electrocuted. People have been killed by falls from ladders after being startled by an electrical shock. The shock certainly contributed to the death but this is not an electrocution. With rare partial exceptions — generally not salient to arrest-related-deaths — the presence of other disease states does not make someone significantly harder or easier to electrocute. Conversely, low-power electrical currents do not hasten deaths from other diseases.

Electrocution causes a potentially lethal cardiac arrhythmia of VF within 1-5 seconds, with immediate loss of pulse, and collapse within another 5-10 seconds. Someone exerting themselves vigorously would collapse more rapidly.

I. How is Electrocution Diagnosed?

There are 6 primary diagnostic criteria required to diagnose an electrocution as shown in Table 6.

Table 6. Diagnostic criteria for electrocution.

	Criterion	Duration	Details Section
1	Sufficient current delivered to heart.	1-5 seconds.[95]	How Close is Close;? Electricity Does Not Build Up Like Poison.
2	Loss of pulse.	Instant[14]	The Significance of the Loss of a Pulse.
3	Loss of consciousness.	10-20 seconds if laying down.[12]	Loss of Consciousness is Rapid.
4	Loss of normal breathing.	15-60 seconds.[14, 15]	Breathing Cessation is Rapid
5	Successful defibrillation.	14 minutes with any CPR; 9.5 minutes without.[96]	Diagnostic Implications of Failed Defibrillation Attempts.
6	VF rhythm.	30 minutes after which the VF typically deteriorates to asystole or PEA.[97-101]	Cardiac Arrest Rhythms

J. How Close is Close?

A few small swine have been put into VF by a TASER X26 CEW with pulses delivered very close to the heart. It must be note that swine are exquisitely sensitive to the electri-

cal induction of VF and a human being requires 2.5 times as much current in order to have VF.[31]

In canines and humans the Purkinje fibers (which carry the heartbeat signal) are confined to a very thin endocardial layer.[102] In swine they cross the entire ventricular wall.[103] It has been recently demonstrated that activation in swine proceeds from the epicardium to the endocardium (outside-in) while in canines and human it proceeds in the reverse direction (inside-out).[104] Swine hearts are literally wired outside-in compared to humans and canines and are considerably more sensitive to external electrical currents. In addition swine have a reduced diastolic reserve and significant differences at the cellular level.[104]

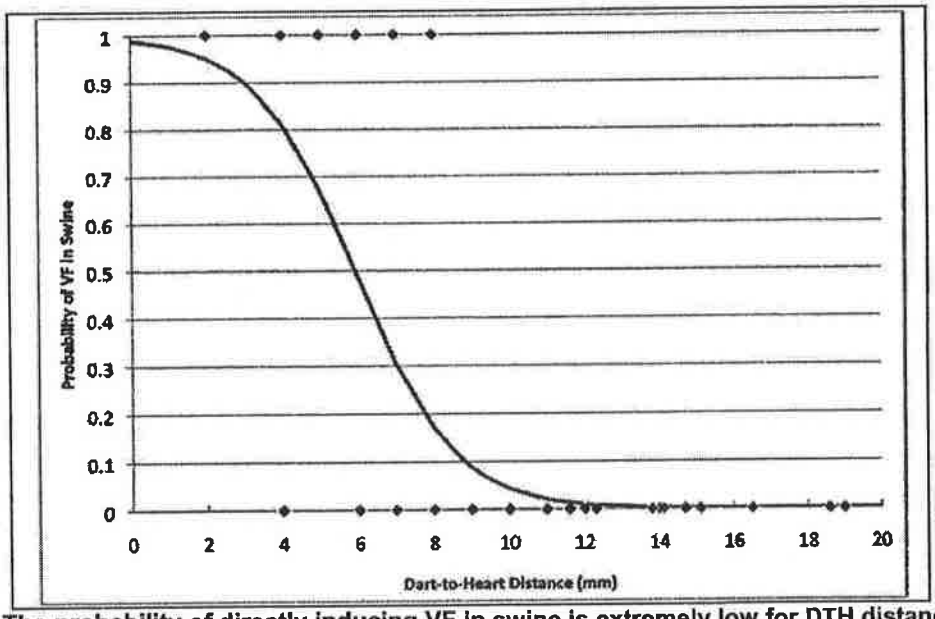

Figure 5. The probability of directly inducing VF in swine is extremely low for DTH distances beyond 12 mm.

As is well known, an X26 CEW can — in rare circumstances — induce VF in a small enough swine if a probe is close enough to the heart.[30] This was studied by the University of Wisconsin Biomedical Engineering Department (for spacings of 2-12 mm) and the detailed results have been published. Lakkireddy et al also tested close probe spacing to the heart (12.3-22.9 mm) without inducing VF.[32, 105] Based on those results, the probability of inducing VF (in swine) based upon dart-to-heart (DTH distance) can be calculated from the accepted statistical model of logistic regression.[106]

The probabilities are shown in Figure 5.

The probability of inducing VF is less than 1 per million for dart-to-heart spacings of 25 mm (1 inch) in swine.

It is also important to put the small swine (with CEW-induced VF) in perspective with the human sized swine that are never put into VF. It is well recognized that any poison or therapy effects depend on the dosage in proportion to the body weight. I.e. a heavier

subject requires more of a drug or poison for the same effects. This is, of course, also true for electrical current whether utility power or CEW pulses.[2, 107] The VF threshold has been evaluated in animal sizes from small rabbits to ponies as seen in Figure 6 taken from Geddes.[2]

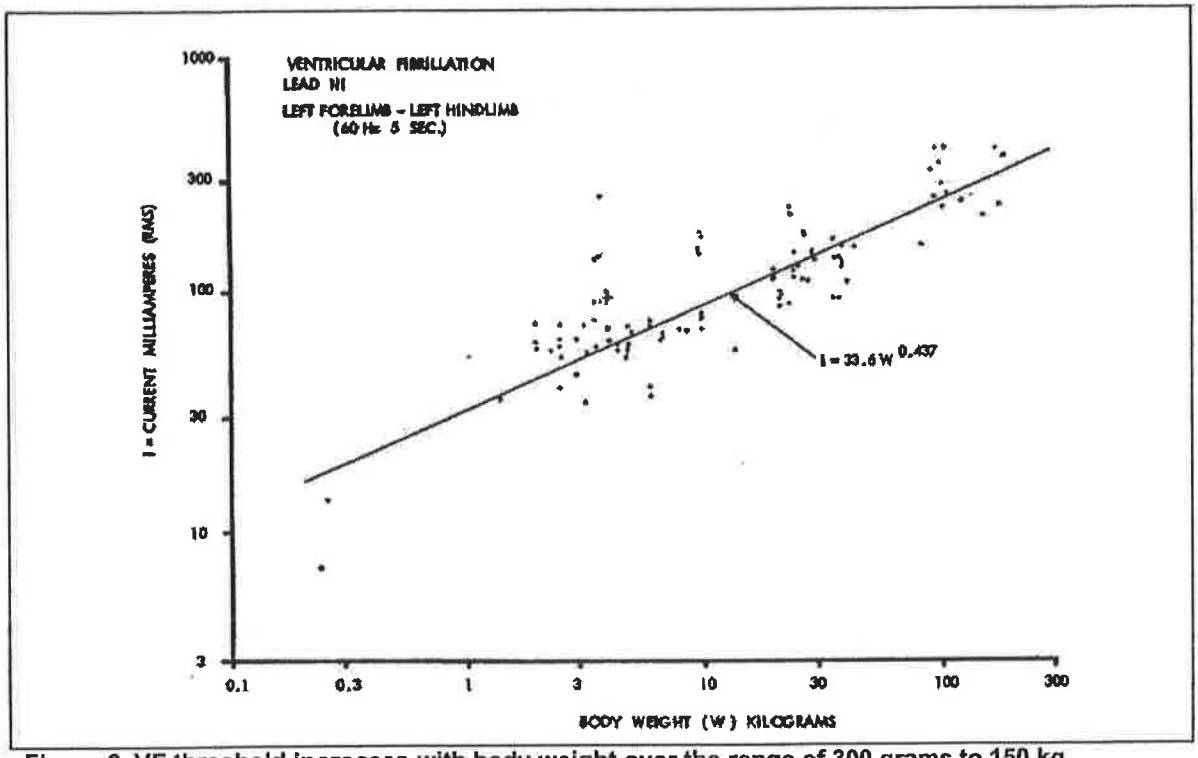

Figure 6. VF threshold increases with body weight over the range of 300 grams to 150 kg.

In 2009 we found 9 published swine studies of the TASER X26 CEW in swine reporting a total of 122 chest exposures with a total of 5 inductions of ventricular fibrillation (VF). The risk of VF was well fit to the animal weight by a logistic regression model (r^2 = .60, p = .0005). See

Figure 7. The risk of VF appears to be confined to small swine. An extension of the model to the mean excited-delirium fatality human weight, of 91 kg, predicts a risk of VF of 8 $x10^{-13}$. These results were presented at both the American Academy of Forensic Science and the Heart Rhythm Society meetings.[49, 108]

The swine data suggests that the human VF risk ceases at a body weight of about 66 pounds.

Critical Dart-to-Heart Distance in Humans

The critical DTH distance in humans will obviously be less than that in swine since swine are so much more sensitive to external currents inducing VF. We now have enough data so that this can be quantified as seen in

Table 7.

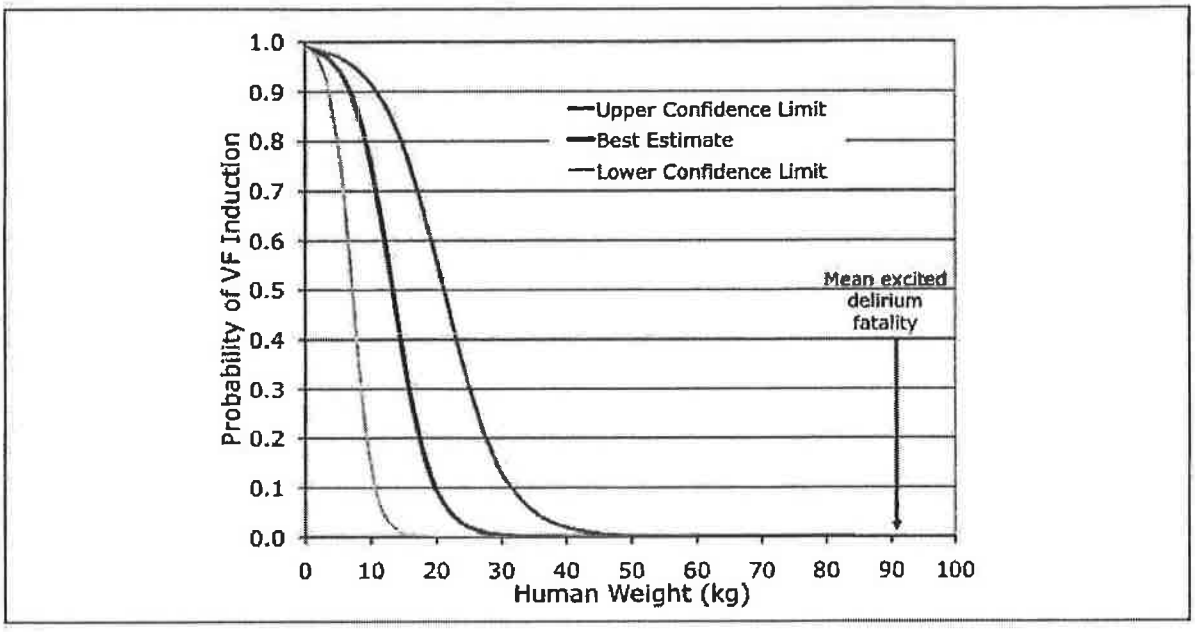

Figure 7. Meta-analysis of swine VF studies shows that the human risk stops at about 30 kg.

As discussed earlier, the Webster group established that the DTH in swine (for the higher charge X26 CEW) was 5.80 ± 2.04 mm with a maximum value of 8 mm.[30] Walcott et al recently showed that swine are 2.5 times more sensitive for the induction of VF for a probe over the right ventricle (which is the heart area closest to the skin).[31]

Table 7. Dart-to-heart distance for VF in humans with high catecholamine levels.

Condition	VFT Ratio	DTH Ratio	DTH mean	DTH stdev	Maximum	Notes:
Swine			5.8	2.04	8	Wu-Webster
Human	2.5	2.08	2.79	0.98	3.84	Walcott
Maximum Epinephrine	0.74	0.79	3.55	1.25	4.89	Han-Moe 26% reduction

A "linear" relationship between the current density and DTH would suggest dividing the 5.8 mm swine value by the 2.5x swine-to-human ratio to get a predicted human DTH distance of 2.32 mm. However, the current density varies with the distance from the tip by a -1.25 exponent so the correction is not quite as great.[43, 109] Hence the DTH ratio (between swine and humans) is given by:

$2.08 = 2.5^{4/5} = 2.5^{0.8}$

This 2.08 DTH ratio then gives a human DTH for VF of 2.79 ± 0.98 mm with a maximum of 3.84 mm. With high levels of infused epinephrine the VF threshold briefly drops by up to 26%.[110] As seen in the Table, this would increase the human DTH for VF up to 3.55 ± 1.25 mm with a maximum of 4.89 mm. That study used infusion rates that would generate blood epinephrine levels over 100 times those seen from a 15-second X26 CEW exposure.[37, 111]

With extreme epinephrine infusions, the maximum human VF DTH distance only increase about 1 mm to about 5 mm.

K. Electricity Does Not Build Up Like Poison

It is often mis-alleged that multiple CEW applications are somehow more dangerous than a single standard 5-second CEW application. This can seem to be very intuitively appealing as multiple baton strikes and multiple bullet wounds are more dangerous than single ones. This intuition is, however, completely wrong and contrary to decades of scientific research. Due to the prevalence of this false intuition — even among many engineers, physicians, and pathologists — it may be helpful to present a fairly lengthy discussion of the scientific facts below.

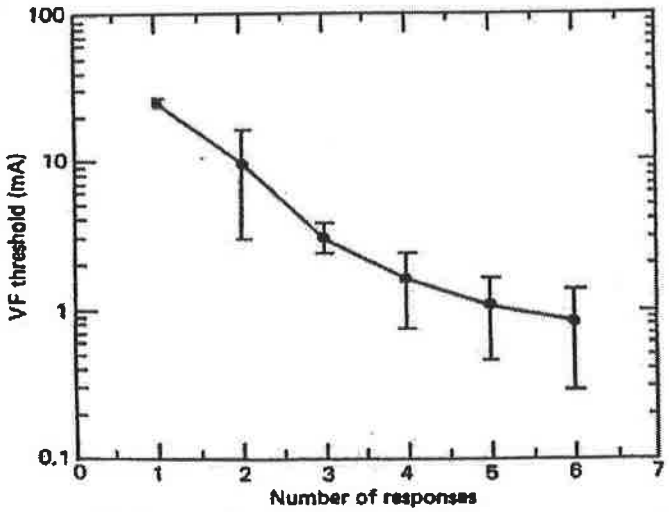

Figure 8. The VFT declines with the number of captured cardiac cycles up to about 6.

The ability of an electrical current to induce VF is characterized by the VFT (VF threshold), which refers to the amount of electrical current required to induce VF. As seen in Figure 8, the VFT declines until about 6 rapid new heartbeats are caused. [112] (Others suggest that it declines up to the point of launching up to 10 new heartbeats.) This is enough to launch enough new waves inside the heart to lead to VF.

The rapid heartbeats have to occur at a rate of at least 400 BPM (beats per minute) in swine.[105] Consider an example of 420 BPM capture and 7 extra beats to simplify the arithmetic. This would take 7/420 of a minute or exactly 1 second. That is why VF generally takes about 1 second to induce electrically. This is consistent with the results of Roy with an electrode inside the canine right ventricle as seen in Figure 9.[90]

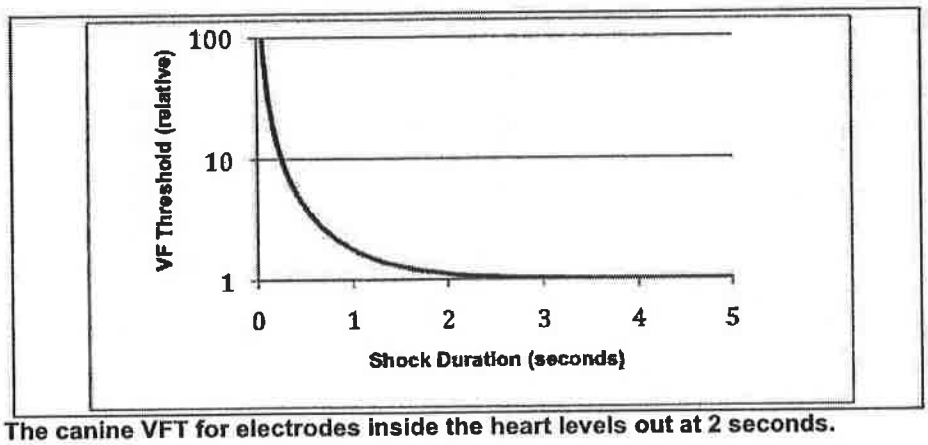

Figure 9. The canine VFT for electrodes inside the heart levels out at 2 seconds.

In fact, 1 second is the official implied value used by UL for their electrical safety standards. [95] The IEC uses a more gradual transition out to about 3 or so seconds as seen in Figure 10. Note that the UL has a slightly stricter safety limit for VF than does the IEC but that is not relevant to this discussion.

These standards are supported by numerous animal and human studies. The "transition time" is the number of seconds after which VF is either induced or not induced with a certain level of electrical current. A summary of studies of the transition time is given in Table 8

Table 8. VF transition times from various studies

Author	Model	Transition Time (seconds)
Antoni[86]	guinea pig	0.8
Wegria[87]	exposed dog hearts	0.2
Ferris[88]	sheep	1.4
Mr. Firmanen[89]	swine	4.0
Roy[90]	dog	2.0
Scott[93]	dog	< 3.0
Kiselev[94]	dog	< 5.0

Using calculations based on the human heart rate, Biegelmeir and Lee determined that the transition time for humans is 2-5 seconds.[1, 91] In a human study, Swerdlow et al showed that the VFT decreased by 47% with durations going from 1-5 seconds, consistent with the calculations of Biegelmeier.[92]

In a canine study, Scott et al found that the VFT did not change with durations going from 3 out to 60 seconds.[93] Kiselev also found the VFT to be quite constant from 5 to 30 seconds.[94]

Scott states in his conclusions:

> Shocks of 3, 10, 30, and 60 seconds duration produced very similar mean [VFT] values. The stability of mean [VFT] over this wide range of shock duration sug-

gests a basal threshold of fibrillation. Currents below this threshold seem unable to induce fibrillation regardless of shock duration.[93]

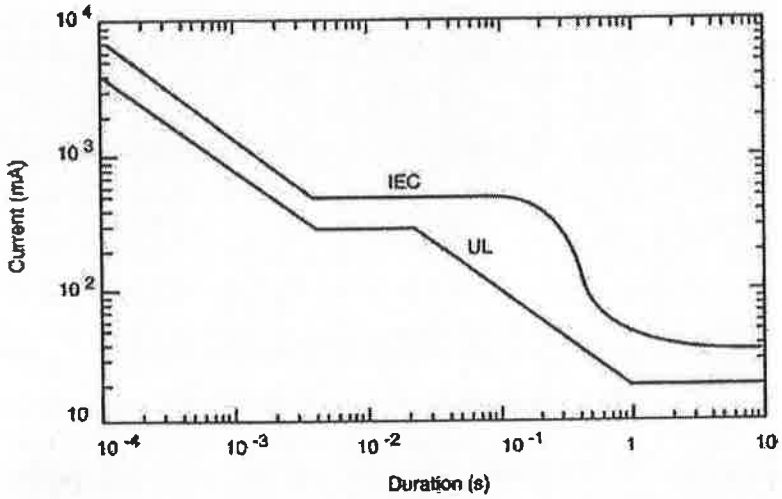

Figure 10. UL and IEC standards recognize that VF is induced within 1-5 seconds or not at all.

Scott's study showed that nothing happens between 3 and 60-second applications of current. Importantly he did this study in 16 canines, which have hearts that are electrically similar, unlike pigs, to humans.[104, 113-116]

The direct electrical induction of VF by electrical currents takes 1-5 seconds.

The Single Exception to the "Poison" Rule.

There is one exception to the electrical poison rule. It involves such rare circumstances that it was only appreciated within the last 2 years.[4] The effect has been demonstrated in swine and canines but will probably never be seen in humans due to the unusual circumstances required to allow it.[62, 63, 117, 118]

This involves the steps of delivering sufficient current with an intact completed and maintained circuit, with a CEW probe perforating the epidermis, dermis, dermal fat layer, muscle layer, and intercostal muscle layer, in the very small sensitive region between the ribs over the heart, to cause high-rate cardiac capture, causing cardiac output collapse, leading to ischemia (for sufficiently long duration) which then lowers the VFT to the level of the capturing current and results in VF. This requires about 40% of the normal VF-induction current but requires a continuous CEW exposure duration closer to minutes instead of seconds for the VF to be induced. The required time for continuous current applications (in swine) causing sufficiently high-rate cardiac capture to cause cardiac output collapse leading to ischemia is 90 seconds; for interrupted applications it is 150 seconds (300 seconds total).[4, 118] Importantly, Roy reported that the same effect required a median time of 240 seconds in canines.[117] Since the canine heart is far closer (electrically) to the human heart than is the swine heart, the 240-second (4-minute) duration is arguably closer to the time required for a human.[104, 113-116] This is consistent with the UL electric fence rule allowing high rate pulsing for 3 minutes.

This would still require a CEW probe tip to be within about 10-17 mm of the human heart and delivering sufficient charge to the heart to induce the continuous high-rate capture to result in sufficiently lowering the VFT.

There is a freak theoretical exception to the rule that electricity does not build up like poison but that situation does not apply to any arrest-related death cases so far.

L. The Significance of the Loss of a Pulse

With VF (ventricular fibrillation — which is the rhythm of electrocution), the pulse is instantly lost. [14] There is not even a single later pulse. The detection of a pulse anytime after an ECD application clearly eliminates ECD electrocution.

It is sometimes argued that pulse detection is inaccurate and there is some truth to this. However, the inaccuracy lies in the inability of responders to quickly find a pulse. For example, if a responder is pushed to find a pulse in 10 seconds or less, about 30% of the responders will fail to find one as shown in Figure 11.[119] Given a full minute, they will almost always find the pulse with 97% accuracy.[119] That is, however, actually irrelevant in most arrest-related death cases. Here the question is about false positives, i.e. what are the chances that a responder will detect a pulse that is not there? Studies show that when a pulse is detected, this has a 95% accuracy.[120]

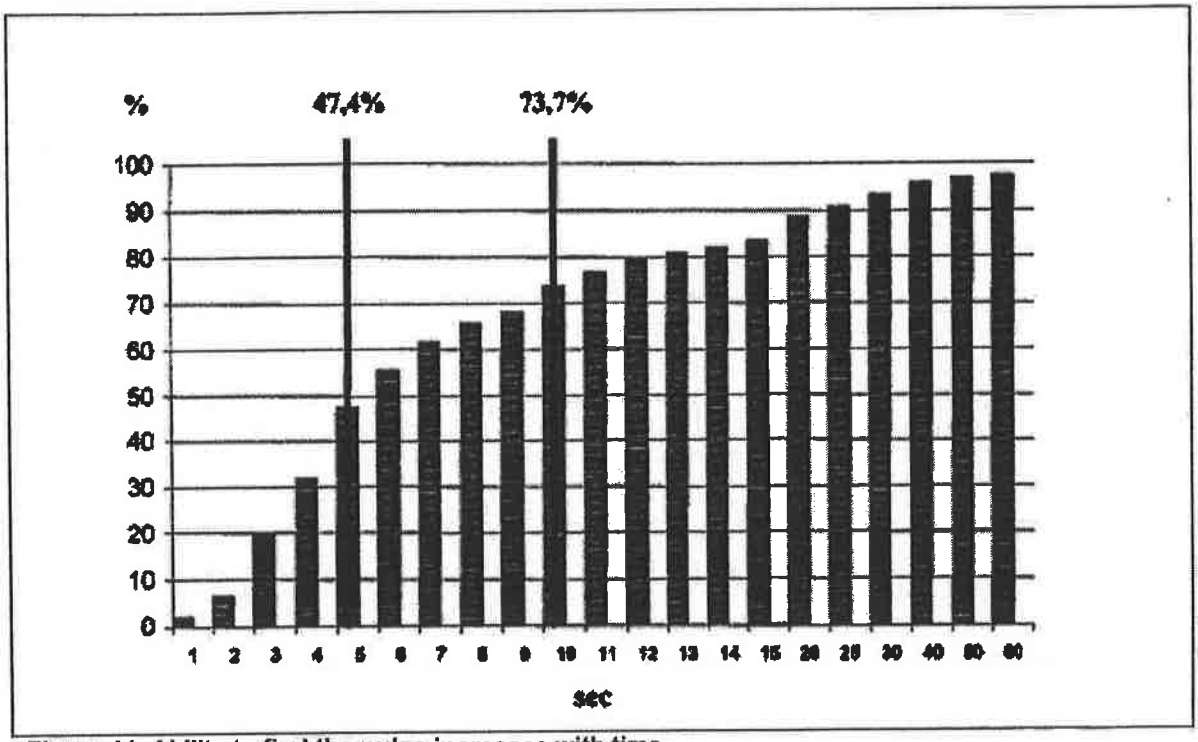

Figure 11. Ability to find the pulse increases with time.

M. Loss of Consciousness is Rapid

A very common diagnostic error is the confusion of postural collapse with a cardiovascular collapse (a sudden loss of effective blood flow). In the normal course of life, a postural collapse is, correctly, often associated with a cardiac arrest.[121, 122] However, it is often forgotten that the design goal of a CEW is to cause a postural collapse to stop aggression.[123] A sternal rub response is often blunted by the presence of alcohol, illegal drugs, and endorphins from the struggle and hence nonresponsiveness is more difficult to evaluate in the law-enforcement scenario.

A person laying down will lose consciousness in typically 14 seconds after an electrically induced cardiac arrest.[12]

Consider a case where a CEW application resulted in a collapse within 1 second. This is typical timing for a successful CEW application and would be reported as an "immediate" collapse. However, if the CEW had induced VF (which takes about 1 second itself) then the arterial blood pressure would not collapse for another 2-3 seconds and the loss consciousness and fall would not occur until about 5-10 seconds after the start of the CEW application. [11, 13]

Thus, ironically, a sudden postural collapse during an CEW application is diagnostic of a successful CEW probe-mode application and *not* of a cardiac arrest caused by electrocution from the CEW.

Typical cardiac arrest diagnostic criteria such as a postural collapse and "non-responsiveness" can give misleading information with an arrest-related death.

N. Breathing Cessation is Rapid

With an electrocution normal breathing will ceased within 12-60 seconds.[14, 15]

Breathing cessation is so temporally coupled to an initiating cardiac arrest that the current AHA (American Heart Association) guidelines rely *solely* on breathing to identify a cardiac arrest.[124] The current AHA rule:

> The lay rescuer should not check for a pulse and should assume that cardiac arrest is present if an adult suddenly collapses or an unresponsive victim is not breathing normally.

There is a red herring that is occasionally invoked in attempts to explain away records of breathing many minutes after a speculated electrocution. This is untenable for 2 significant reasons:

1. Law enforcement officers have "first responder" training and can tell the difference between normal and agonal breathing. After all, the AHA expects untrained bystanders to do this.
2. Agonal breathing typically lasts only 3 minutes in humans and slightly longer in swine.[125, 126] As seen in Figure 12 it is very rare beyond 6 minutes.

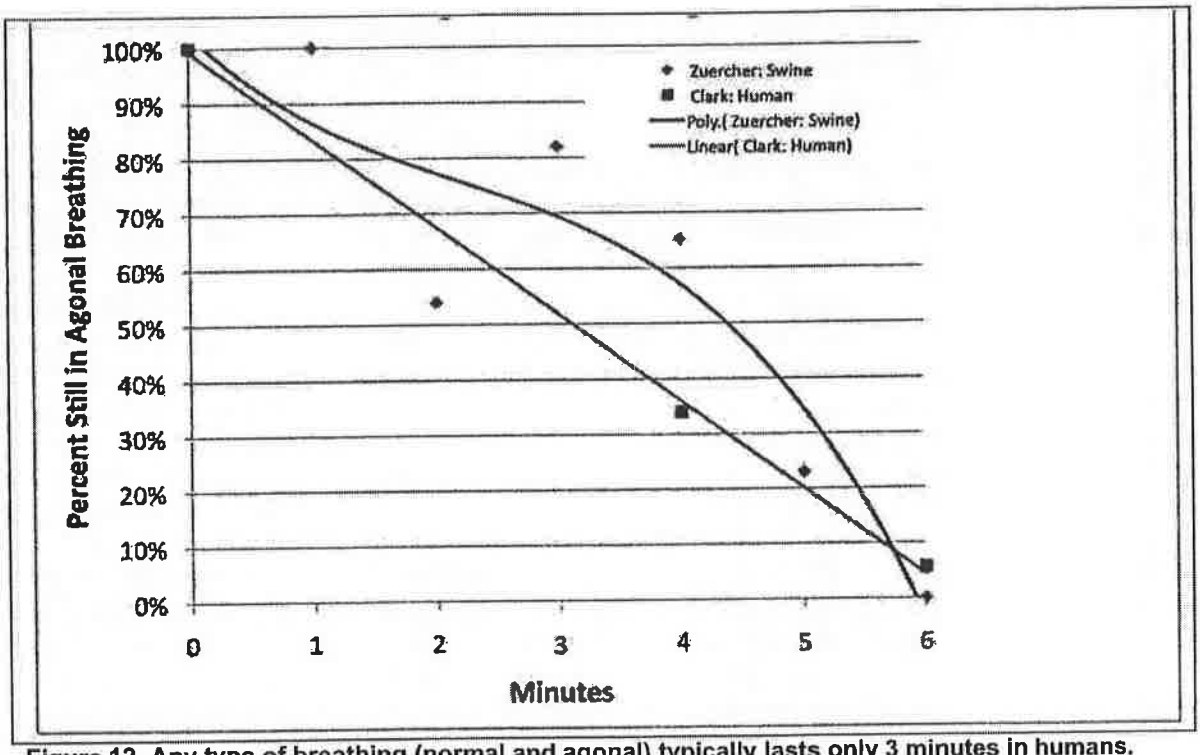

Figure 12. Any type of breathing (normal and agonal) typically lasts only 3 minutes in humans.

O. Diagnostic Implications of Failed Defibrillation Attempts.

An electrically-induced VF is almost always reversible by a defibrillation shock. This is demonstrated every day with ICD (Implantable Cardioverter Defibrillator) implants.[127] The experience of over 1 million ICD implants teaches us a very important lesson. Most implants involve inducing VF electrically in order to test the ICD's proper operation.[127] Electrically induced VF is very easy to convert — especially in younger people such as the subject of this case. With an ICD implant the shock is typically given in 10-20 seconds after the induction of VF and the success rate is essentially 99.98%.[128]

Even without cardiopulmonary resuscitation (CPR), electrically-induced VF is easily defibrillated after 7 or 8 minutes.[129, 130] With pre-shock CPR (as usually delivered by law-enforcement officers) electrically-induced VF is still easy to defibrillate after 8 minutes.[131]

This should not be confused with ischemically-induced VF episodes where the defibrillation success rate was only 43% after 8 minutes.[131]

Table 9 shows the number of animal studies that have reported the success of defibrillation (sometimes allowing multiple shocks) for *electrically-induced* VF for various VF durations out to 12 minutes. (*ROSC is number of animals with Return of Spontaneous Circulation.)*

Table 9. Defibrillation success vs. minutes of electrically-induced VF.

Study	Year	N	Mins of VF without CC	Mins of Pre-shock CC	Mins Total in VF	N w ROSC	Notes
Yamanouchi[132]	1999	12	1	0	1	12	
Allred[129]	2008	6	7	0	7	6	
Tang[133]	2006	21	7	0	7	18	No CC before 3 shocks
Tang[133]	2006	21	7	0	7	19	CC after failed shock
Niemann[131]	2007	26	7	1	8	24	6 had coronary ligation before induction
Ewy[134]	2007	33	3-6	6-9	12	21	
Xu[135]	2007	7	7	5	12	5	
Wang[136]	2007	10	7	5	12	10	Used Thumper®
Leng[137]	2001	5	12	0	12	1	
Halperin[138]	2010	9	10	3.5	13.5	9	
Hayes[139]	2007	36	8	6	14	13	Ventilated during VF
Leng[137]	2001	5	12	4	16	5	

N is total number of animals studied and "CC" is chest compressions.

The data from Table 9 (and other studies) were fit to a logistic-regression model to show the dependence of the defibrillation success rate on the duration of VF as seen in Figure 13 ($p = .0073$ by Wald's Chi-square). Left curve (blue) is without chest-compressions while right curve (green) is with continuous compressions. Note that the rate of success is essentially 100% at 5 minutes and essentially 0% at 25 minutes.

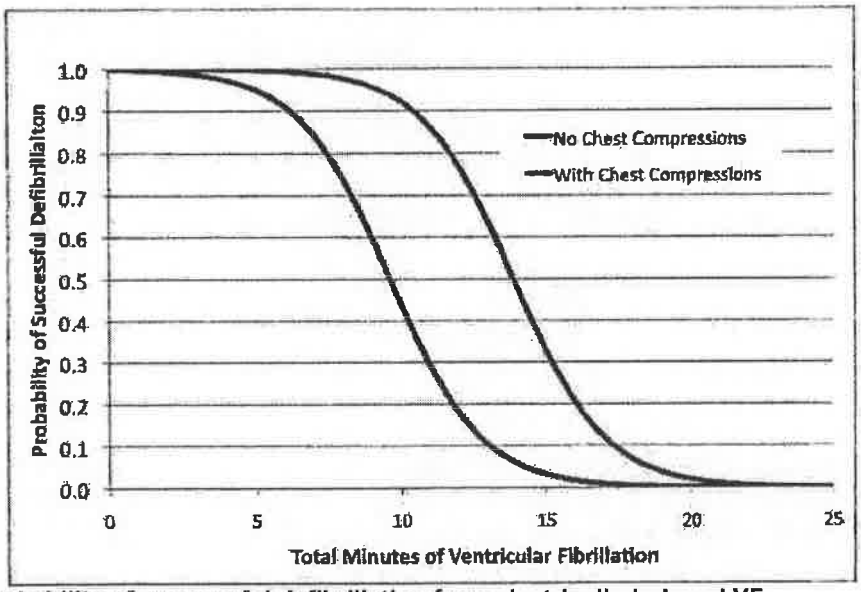

Figure 13. Probability of successful defibrillation from electrically-induced VF.

If defibrillation shocks fail to convert an episode of VF that is less than 10 minutes old, then electrical induction is highly suspect. The most likely explanations for *primary* VF from some sort of cardiac pathology or a drug overdose or secondary VF from asystole pulseless electrical activity that was converted to VF by chest compressions.[26, 140]

P. Cardiac Arrest Rhythms

Occasionally one will hear the comment that a cardiac rhythm of asystole was present simply because a person was in VF for a long time. This comment reflects a confusion between *primary* asystole and *terminal* asystole. Primary asystole is asystole which causes the initial collapse of the person (and is seen with about 1/3 of cardiac arrests from heart disease). [141, 142] Terminal asystole is significantly different. If a person has been in VF, for example, for about 45 minutes, the heart is irretrievably dead and there is no electrical signal at all.[143] (An analogy is to the body temperature which slowly falls to room temperature after death.) Asystole and PEA are the most common cardiac arrest rhythms in deaths due to drug and alcohol abuse or excited delirium syndrome.[19-26]

Table 10. Cardiac arrest rhythms

Rhythm	Inducible electrically?	EKG (electrocardiogram)
VF (ventricular fibrillation)	Yes.[1-4]	Rapid jagged random appearing
Asystole or bradyasystole	No.*[5-10]	Flat-line (pure asystole) or very low heart rate (bradycardia) or rare heartbeat (agonal rhythm). Bradyasystole is often used to refer to this group of rhythms. Asystole is typically defined as a bradycardia with less than 5 or 6 BPM (Beats Per Minute).
PEA (pulseless electrical activity)	No.[5-10]	Repeating electrical signal in normal heart rate range but without cardiac output. Also called EMD (electromechanical disassociation).
VT (ventricular tachycardia)	With preexisting heart disease. [144-147]	VT is not a cardiac arrest rhythm, per se, but is mentioned here to be complete as a rapid (unstable) VT can quickly degenerate into VF. For reasons discussed in the "VT infection" section, VT is not relevant to ARDs (arrest-related deaths), electrocution, or ECDs.

* asystole is sometimes seen after a massive electrical nerve injury such as a lightning strike but that is not relevant as the currents delivered are astronomically higher than those from a ECD.

Modern animal studies have shown that VF cannot decay to asystole in less than 20 minutes.[148, 149] Analysis of primarily ischemically-induced human cases shows that the median time (for VF to deteriorate into asystole *without CPR*) is 19 minutes as shown in Figure 14.[150] Swine data shows that the median time is 34 minutes as shown in Figure 14. The mean value in dogs is reported to be 24 minutes.[151] With good CPR (cardiopulmonary resuscitation) the delay — from VF to asystole — could be greater than 60 minutes.[152,18] With defibrillation shocks, the conversion can be more rapid.

Swerdlow et al studied the cardiac arrest rhythms in ARDs (arrest-related deaths) where a CEW had been used.[153] In 8 of these cases the subject was on a cardiac monitor ***before*** the collapse. In all of these cases, the subject went directly from a normal ("sinus") cardiac rhythm to asystole. (There may have been 1 case with PEA.) *In no case was there a VT or VF before the asystole.*

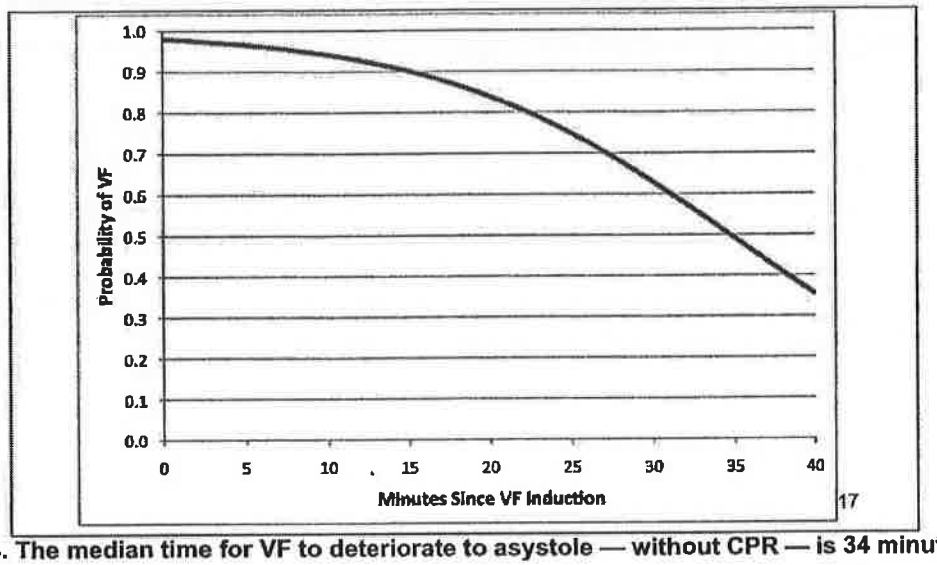

Figure 14. The median time for VF to deteriorate to asystole — without CPR — is 34 minutes.

Q. Ventricular Tachycardia and the Curious Electrical Infection Theory

A creative speculation — that has been raised to attempt to argue for a long gap between an ECD electrical exposure and VF — is that the electrical current infected the body with an intermediate cardiac rhythm called VT (ventricular tachycardia). This elaborate scientifically unsupported hypothesis consists of the following steps:

1. The CEW allegedly induced a VT.
2. This VT allegedly infected the subject but not so badly that he was unable to maintain consciousness and keep resisting.
3. The VT then allegedly deteriorated into a VF.
4. And, that is why the subject was able to keep fighting for minutes after the ECD exposure even though it is universally accepted, and not seriously contradicted, that VF is induced within a few seconds and a subject (in VF) will pass out in a few more seconds.

Definitions:

1. VT: a rapid heartbeat that starts in the ventricles.
2. Sustained VT: a VT that lasts for more than 30 seconds.
3. Unstable VT: a VT that causes symptoms — most commonly passing out (syncope). Note that the word "unstable" refers to the effect of making the person's blood pressure unstable — not the VT. I.e. a sustained unstable VT is one that persists but makes the person faint.

This "electrical infection" speculation for ARDs is scientifically unsupportable for several reasons including:

1. A sustained VT cannot be induced absent significant cardiac scarring from a previous myocardial infarction (heart attack).[144-147] By definition, only a sustained VT would possibly allow a delay to cardiac arrest of more than 30 seconds.

2. A VT that will lead to VF is almost always an "unstable" VT. An unstable VT will degenerate into VF within 34 ± 7 seconds in humans.[154] Hence, there could not be a VF delayed by, say, 60 seconds.

3. Any VT that leads to VF has such a rapid heart rate that it almost always leads to immediate syncope (loss of consciousness).[154, 155]

4. VT induction generally requires specialized pulse timings and is generally not inducible with steady rate currents such as those from an CEW.[144, 156]

5. VT has never been documented in the literature as a cardiac rhythm in ARDs (arrest-related deaths) where an CEW was temporally used.[153, 157]

6. A theoretical induction of VT would still require high-rate cardiac capture. This requires a probe tip to be within 1.67 cm (centimeters) of the heart — while possible with a perfect shot and a very thin person — has yet to be documented.

1. A Sustained VT Requires a Scar From an Old Infarct

In the 1980s there was interest in the issue of sustained VT and important studies were done by now-famous researchers, Brugada, Wellens, and Morady. They concluded that a sustained VT could not be induced in someone with a normal heart. [144-147]

As shown in Figure 15, the principle mechanism for a sustained VT is that an activation wave chases itself around an old infarct scar like a dog chasing its tail around a small tree. If there is no scar from an old infarct (heart attack) then there is no "substrate" to support the sustained VT.

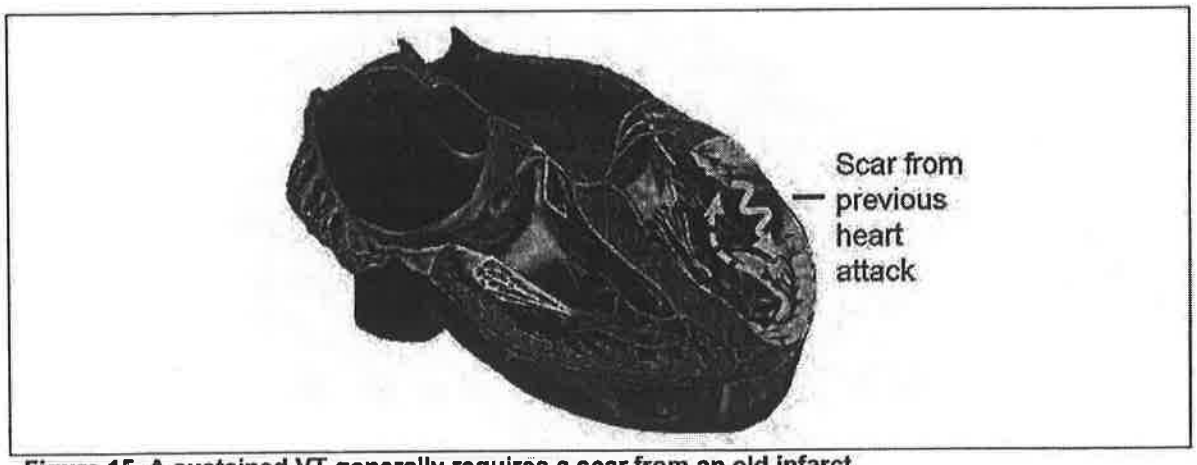

Figure 15. A sustained VT generally requires a scar from an old infarct.

A small exception is HCM (hypertrophic cardiomyopathy). In some HCM patients a sustained VT can be induced with specialized pulse sequences but this is not expected.[144] There are some very uncommon VTs that do not require a diseased heart. These are:

1. RMVT (repetitive monomorphic VT)
2. PSMVT (paroxysmal sustained monomorphic VT)
3. ILVT (ideopathic left VT)

RMVT is not relevant as it is nonsustained.[158] It is also difficult to electrically induce and is not associated with cardiac arrest.[159] Both PSMVT or ILVT are very symptomatic and associated with syncope so they are also not relevant.[160]

2/3. A VT leading to VF Must Be an Unstable VT

Huikuri showed that a VT that degenerated into VF lasted only 34 ± 7 seconds and the subjects went unconscious 100% of the time with the VT. [154] The time required for the deterioration of 34 seconds was for a patient resting on a catheterization lab table. It would be much less for someone fighting or running around. Figure 16 shows this timing.

Stevenson found that the induced VTs in VF patients had an average VT rate of 242 BPM.[155] It is not expected that someone could keep fighting with a 242 BPM VT. Or, that a pulse could even be detected.

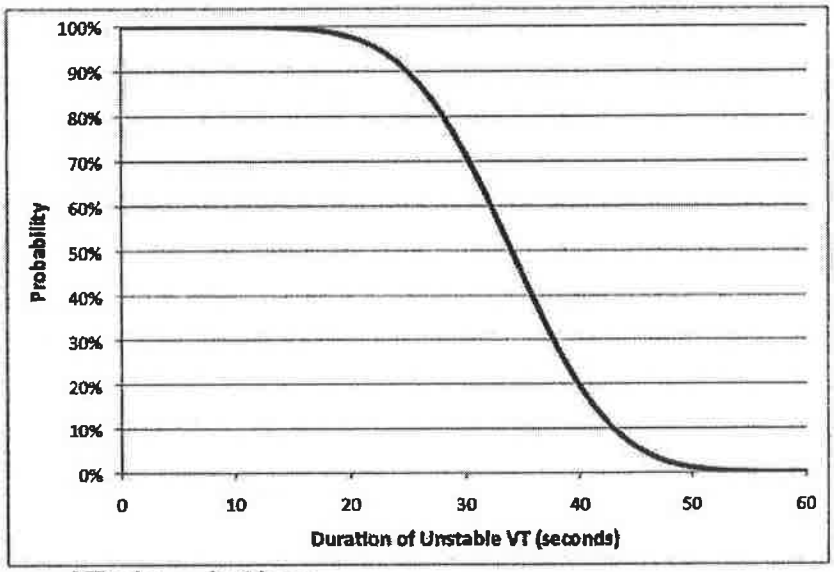

Figure 16. Unstable VTs do not last long.

In the Nanthakumar swine study, a VT was induced (probably by a large simultaneous infusion of epinephrine) and it only persisted for 7 seconds.[161] Meanwhile its blood pressure was 40 mm which means it would have been unconscious (had it not been already anesthetized).

4. VT Induction Generally Requires Specialized Pulse Timings

With steady regular currents such as those from a CEW, the induced arrhythmia is VF and VT is simply not reported in patients.[156, 162]

5. VT has Never Been Documented with A TASER CEW Incident

VT has never been documented in the literature as a cardiac rhythm in ARDs where a CEW was used.[153, 157]

One might attempt to speculate that a CEW-induced VT always disappears before EMS (emergency medical services) shows up. However, according to the Swerdlow paper, in many cases of deaths temporal with CEW usage, the suspect was being cardiac monitored *before* any arrhythmias developed. And in these incidents VT was also not seen.

6. A Theoretical induction of VT Would Still First Require High-rate Cardiac Capture.

In the swine model, this requires a vector with a probe tip within 23 mm of the heart.[32, 105] Extrapolating to humans by correcting for the higher sensitivity of swine gives a ~17 mm dart-to-heart for the human heart.[29] While this is possible with a perfect shot placement and a very thin person, with a fully penetrating probe, it has yet to be documented in the literature.

Peer-reviewed Literature Comments on the VT Infection Theory

The 2011 Vilke review [Position Paper of the American Academy of Emergency Medicine] also casts significant doubt on any delayed effects of a CEW application:[65]

> These studies did not report any evidence of dangerous laboratory abnormalities, physiologic changes, or immediate or delayed cardiac ischemia or dysrhythmias after exposure to CEW [Conducted Electrical Weapon] electrical discharges of up to 15 seconds.

The 2011 Pasquier review observed:[163]

> A delayed cardiac arrest may be explained by the occurrence of ventricular tachycardia degenerating into ventricular fibrillation some minutes or hours after exposure. However, this seems improbable in healthy subjects, as is the hypothesis of myocardial necrosis as a result of electrical lesion leading to ventricular arrhythmias minutes or hours after electronic control device exposure.

The Ideker analytical paper concluded:[56]

> Therefore, it is highly unlikely that the TASER X26 [CEW] can cause ventricular fibrillation minutes to hours after its use through direct cardiac effects of the electric field generated by the TASER.

This Little Pig Went to Tachycardia

Since the scientific evidence, against the VT infection theory, is overwhelming, TASER CEW critics are forced to build their theory on a single pig. It is said that anecdotes and animal studies are weak evidence for anything so a single animal anecdote has to be the weakest underpinning that one could have.

Here is the quote from a deposition ((NV) Rich, May 23, 2011):

> Q And how long can that sustained VT in a normal heart last? How long can it continue?
> A Oh, it will vary tremendously. In the pig data we have sustained VT for three minutes, and that's a normal pig heart. So it certainly can happen in humans.

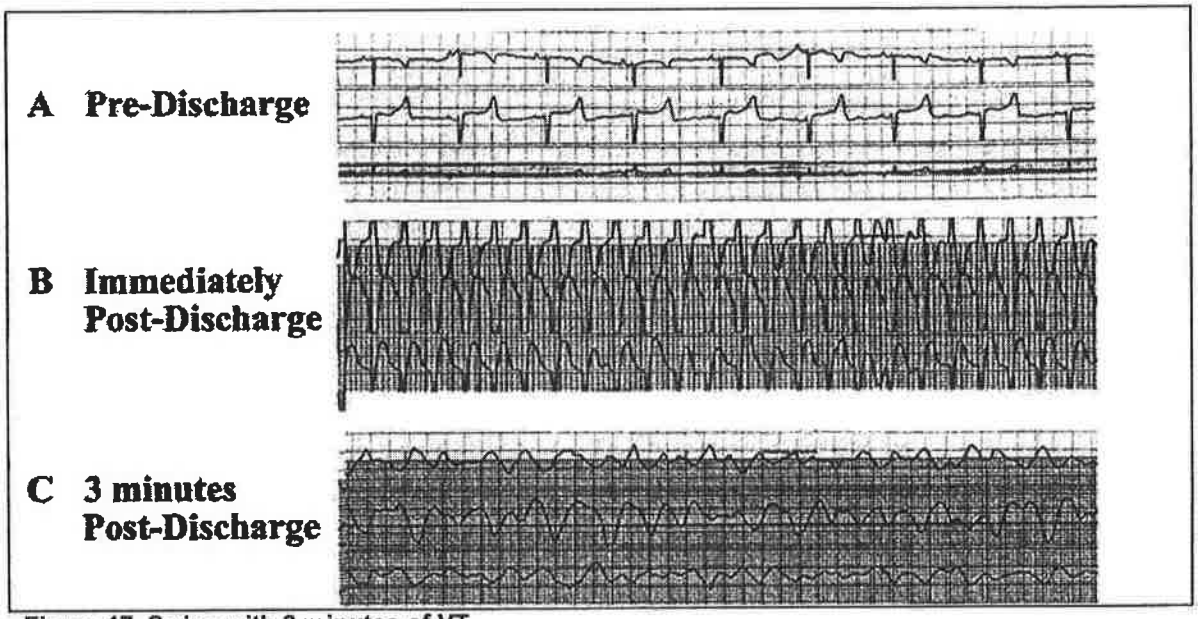

Figure 17. Swine with 3 minutes of VT.

There is indeed an example of a swine with an electrically-induced VT lasting 3 minutes which appears — at first blush — to contradict the human data that a sustained VT generally requires an infarct scar. I.e. that a sustained VT cannot be electrically induced in a "normal" heart. See Figure 17 taken from Dennis et al.[62]

There are several problems with relying on this single swine:

1. Human studies trump or supersede animal data — not the other way around.
2. This pig may have started out with a normal heart but it was far from normal when this VT was documented. The pig received 80 seconds of high-rate cardiac capture which would cause severe myocardial ischemia. On top of that, the anesthetized pig was not allowed to breathe during the 80-second CEW application (40 s on, 10 s break, and then 40 s on), which would have exacerbated the ischemic acidosis.
3. Not only was this seen in only 1 of the 6 swine tested (and has never been replicated), a sustained VT has never been documented in numerous swine studies where the animals were allowed to breathe.[4, 32, 46, 105, 107, 161, 164] There was a single

case of *nonsustained* VT (7 seconds) in a swine right after an epinephrine infusion was begun.[161]
4. The high rate of the VT would have resulted in a loss of pulse and consciousness and thus is not applicable to the typical human ARD case where delayed VF is asserted.
5. Small swine were used to ensure that the probes could be close enough to the heart to obtain capture. This 29 kg swine is hardly representative of the typical ARD weighing 91.8 ± 18.2 kg.[157] ($p < 0.000001$)

This is truly a case where the extreme exception demonstrates the rule.

The speculation that an CEW could infect the body with a subclinical VT — leading to a VF cardiac arrest but more than a minute — violates up to 6 scientifically established facts.

Q. Animal Anomalies and Human Anecdotes

The large body of animal and human studies is essentially unanimous regarding the cardiac safety of CEW. None of the numerous human studies have found any cases of VF induction with an CEW.[37-40, 50, 53, 54, 58, 64, 165-178] Of note, none of the numerous CEW animal studies have found any statistically significant tendency for the induction of VF.[32, 107, 179-184] There have been a few animal studies and human anecdotes that are sometimes mischaracterized to inappropriately attempt to suggest a danger of VF from TASER CEWs. (The Webster-Wisconsin studies using special long electrodes nearly touching the heart are discussed elsewhere.) The fact that there are so few anecdotes out of over 3 million human CEW applications is strong evidence of the ECD safety.

Nanthakumar Single Swine

The Nanthakumar swine paper is often mis-characterized and mis-appropriately cited as it presents the ***single*** case of a larger (50 kg) mammal put into VF supposedly by a TASER CEW.[161] Note that 50 kg equals 110 lbs and thus this animal is considerably lighter than the human in this case. This paper has significant limitations that cast doubt on its applicability or extrapolation to adult humans.

1. The chest probes were inserted directly across the heart of 6 pigs. The spacing is not given but can be estimated to be about 1-2 cm away from the heart.
2. There were 150 CEW discharges, including 94 thoracic discharges, into the 6 pigs.
3. *No VF was induced with the CEW applications in any of the pigs.*
4. Nanthakumar then began a very strong infusion of epinephrine. Epinephrine itself can cause VF.[185-190]
5. Epinephrine makes the heart very prone to VF in the first 3 minutes after infusion.[110]
6. VF was still seen in only 1 of the 6 pigs, and then only 1 time out of 16 attempts.
7. *The statistically correct conclusion is that there was no tendency for VF since the vast majority of the swine (5 out of 6 animals, or 93 out of 94 thoracic CEW discharges) — with probes across the heart of a 110 pound animal — never had VF.*

8. To eliminate the risk that the epinephrine itself caused the VF, Nanthakumar should have waited a few minutes before beginning the TASER CEW application. This would have given the body time to adjust to the epinephrine. Nanthakumar's paper fails to disclose how many minutes (or seconds), if any, between the start of the epinephrine infusion was of the CEW application; he has also refused numerous requests to disclose that information. Thus, this implies that there was minimal time separation between the continuous epinephrine infusion and the CEW application and that the VF was very possibly induced the single time in the single animal, out of 16 attempts, by the epinephrine itself.
9. Nanthakumar himself said that the results could not necessarily translate to larger humans but "may have relevance to smaller individuals who have died after [CEW] discharges" and cited to an anecdote of a death of a 7-month old infant blamed on some sort of stun gun.[191] Thus it is a long stretch to try to apply the Nanthakumar results to an adult human.
10. In a later clarifying letter, Nanthakumar stated, "[w]e did not state that [CEWs] cause ventricular fibrillation in humans, and we agree that we cannot conclude from our study that [CEW] discharges cause arrhythmias in typical use."[192]

Dennis/Walter Swine Studies

The Dennis paper and the Walter paper can be discussed together.[62, 63]

1. Both studies were done at the same center and Dennis and Walter co-authored each other's papers.
2. This group was associated with a putative competitor (Aegis) that has gone to lengths to malign the TASER products.[33-35] This was noted in a Federal Court decision.[193]
3. Both studies turned off the ventilator during the CEW applications thus interfering with the breathing of the swine. The ventilator was required as the swine were deeply anesthetized and thus could not breathe on their own.
4. Probes were put directly along the heart axis. While the distance (from the probe tips to the heart) was not disclosed, it can be estimated from cardiac capture effects to have been 1-2 cm.
5. No VF was induced in any of the animals with exposures less than 80 seconds (Dennis) and 40 seconds (Walter).
6. It is well recognized that swine are the easiest mammal to fibrillate and thus present a conservative model for estimating electrocution risk.[31, 194-197]
7. The only swine that had VF were the smaller ones (28, 29, and 31 kg). None of the larger animals (up to 71 kg) had VF.

The group quickly realized that — even with extreme scenarios — they could not fibrillate larger swine. They then decided to focus on smaller animals to increase their chances of getting VF.[46] They also used an artificially long 13 mm probe penetration to get closer to the swine heart. (TASER does make a 13 mm long probe but that is to penetrate clothing and the probe does not have the kinetic energy to fully penetrate human tissue.) They were finally able to induce VF in a 2 small breathing swine.

Lakkireddy Studies

Lakkireddy published 2 studies investigating the risk of VF in swine depending on the location of the probes and the presence or absence of cocaine intoxication.[32, 105]

1. VF was never induced in any animal at standard X26 CEW delivered charge despite the location of probes as close as 12.3 mm (1/2 inch) away from the heart.
2. In some cases there was some rapid pacing of the heart (cardiac capture) when the probes were extremely close to the heart.

Ironically, it was once suggested that the Lakkireddy finding of cardiac capture proved the possibility of CEW-induced VF when the *exact opposite* was found. There was no VF found (regardless of the probe positions or the presence of cocaine) in spite of cardiac capture.

Lakkireddy recently concluded in a paper published in September 2010, from this study and a review of the other studies:[196]

> These [animal] studies have shown that having probes directly over the heart (to increase possibility of the electrical current to pass through cardiac muscle), as well as current standard discharge, are safe. Based on [the human] findings, ECD is considered safe from a cardiovascular stand-point.

Kim/Franklin Anecdote (Mr. Watson)

The best known anecdote is found in the famous Kim-Franklin two-paragraph letter to the New England Journal of Medicine published in September 2005, with regard to a February 2005 incident.[198] It is unknown if the 2-paragraph letter was peer-reviewed. It is known that there are errors in the letter. Since the subject, Mr. Akeem Watson, was only 14 years old at the time of the incident it was impossible to get, or even verify, details of the incident until recently.

1. The violent psychiatric subject had a normal pulse and respiration after the CEW was used and thus no arrhythmia or cardiac arrest was induced by the CEW.[199, 200]
2. Mr. Watson was then carried down, on a stretcher-chair, to the ground floor, and put into an ambulance so that his self-induced lacerations could be treated. He was again checked for vitals and the vitals were the same as previously measured. It was in the ambulance after the second vitals check that Mr. Watson finally had VF.
3. It has also been demonstrated that the cardiac rhythm strip shown in the Kim-Franklin anecdote (supposedly demonstrating a return to sinus rhythm by a defibrillation shock) was cropped after what were actually 3 PVCs followed by asystole.
4. This letter has been rebuked in the literature and is no longer taken seriously. [201,202]

Naunheim Anecdote (Mr. Colin Fahy)

A more recent case also claimed that an older teenager (Colin Fahy) had VF induced by a CEW.[203] As Dr. Zipes has testified, Mr. Fahy's presenting cardiac rhythm was asystole.

1. This ECD-induced VF allegation was completely contradicted by the EMS (emergency medical services) records and sworn testimony of the paramedics on scene.
2. This anecdote has been repudiated by other emergency physicians in the *same hospital*. They published that the subject, Mr. Colin Fahy, presented with asystole — not VF — consistent with his extreme levels of ethanol.[204]

Cao Pacemaker Anecdote

Cao et al reported a case of X26 CEW cardiac capture in which the ECD discharge was delivered into the chest of a rioting 53-year old prisoner with a pacemaker.[205]

1. The specific pacemaker involved (Medtronic Kappa, model KDR901) had the typical overvoltage protection circuitry that passes negative potentials from the can (pacemaker housing) to the intracardiac bipolar ring electrode which can cause unipolar cathodal pacing.[206]
2. This caused cardiac capture of ~ 220 BPM (Beats Per Minute) for the duration of the ECD application, but had no lasting effects. The capture rate did not increase over the ECD discharge duration.
3. FEM (finite element modeling) in this case indicates that the CEW field at the heart was much weaker than the stimulation threshold, but the voltage difference at the pulse generator was likely sufficient (5 – 10 V) to permit capture after being channeled to the ring and tip electrodes.[207]
4. No VF was induced.
5. This case has been extensively analyzed and the consensus is that the pacemaker was not a casual observer to CEW-caused capture but the pacemaker itself caused the cardiac capture by conducting the CEW pulses via the pacemaker leads down to the inside of the heart.[206, 208, 209]

Lee/Tseng ARD Paper

While not an anecdote, this interesting paper purported to find an increase in ARDs (arrest-related deaths) in the 1st year after a law-enforcement agency began using CEWs.[210]

1. The hypothesized explanation was that the CEW was overused and escalated confrontations which led to *more firearm shootings*.
2. The authors never suggested that an CEW caused any VF or directly killed anyone.
3. The authors never suggested that an CEW was even present, let alone used or deployed, at any of the ARDs.
4. Dr. Lee then tried to capitalize on his paper as an anti-police expert witness in 2 cases (the (CA) Teran and (AZ) Graff cases. When the judge ordered him to provide the raw data behind his mysterious study, he simply dropped out of the lawsuits.). Dr. Tseng was contracted (in 3 contracts) as a paid anti-TASER expert in the Canadian Braidwood Commission.
5. Dr. Lee has refused to share any of his data with other researchers and authorities in the area do not take his study seriously.
6. This interesting result is contradicted by all other studies which find a reduction in injuries with ECD adoption. [211-221]

Zipes/Burton Case Series

A retired cardiologist published the 8 expert witness cases that had been provided to him by attorney John Burton and a legal associate.[42] The paper was rife with errors including the comment that the subjects were "clinically normal." (This error was corrected in an addendum after being brought up in a deposition.) Numerous other errors have been pointed out including the listing of a case where the CEW probes missed the subject and thus could hardly be blamed for contributing.[222-224] Recently, the journal added the clarification that Mr. Burton had to be acknowledged as a contributor.

R. Electrical Pacing is Helpful and is Not VF

Since small swine can be paced by a TASER X26 CEW — with probes within 23 mm of the heart — some have argued that this "cardiac capture" is the same as inducing VF. (Note that millions of people worldwide have "cardiac capture" every second from their implantable pacemakers.) However, the induction of VF requires cardiac capture at much higher rates.

Just like it takes for gas to make a car go faster, it takes more electrical charge to capture a heart more rapidly. This is so well recognized in cardiac electrophysiology and bioelectricity that it has a special name, "the strength-interval curve." I.e. if one is trying to capture the heart will less of a recovery "interval" from the previous capture then it takes more strength.[225-239] The famous Zipes group and also Luck et al evaluated the strength interval relationship for transcutaneous pacing.[230, 234]

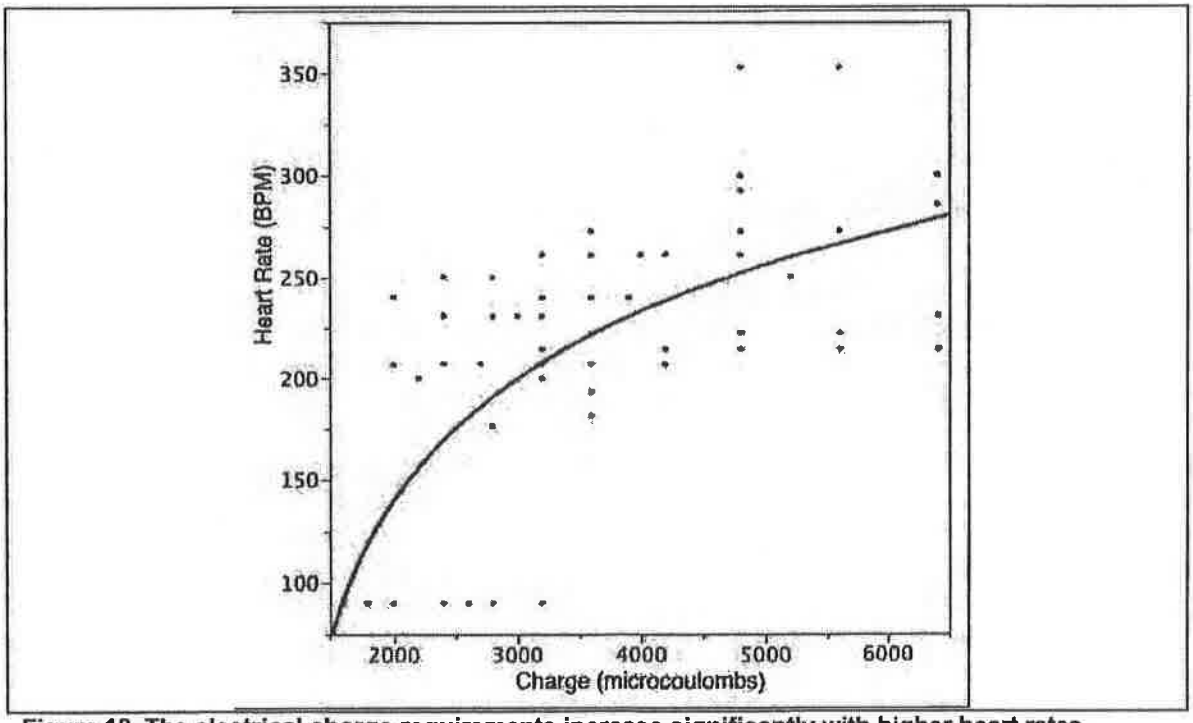

Figure 18. The electrical charge requirements increase significantly with higher heart rates.

Luck determined the dependence of the minimum-coupling interval on the delivered charge with external (transcutaneous) stimulation using large patches. They reported their results in terms of current (mA). To calculate the delivered charge, the current is multiplied by the 40 ms pulse duration of their stimulator. As the delivered electrical charge was increased, the heart rate was increased in a straight-line relationship. However, the average heart rate leveled off at 270 BPM and could not be increased even when the stimulator was adjusted to its maximum output as seen in Figure 18. The range of maximum calculated heart rates at maximum stimulator output was 207-353 BPM.

S. Multiple or Prolonged CEW Trigger Pulls: More is Usually Less

A common misperception, in CEW cases, is that CEW download data showing multiple or prolonged trigger pulls somehow or to some degree implies excessive delivery of current. In fact, the opposite is usually true. The primary reason for multiple or prolonged trigger pulls is that the fragile wires are broken early on in the encounter and the officer continues to pull the trigger, hoping for a response.

The tiny wires (36 gauge, 127 microns in diameter, about the diameter of some human hair) are usually quickly broken during any struggle and are typically broken when a subject turns and falls. The tensile strength, of the wires, is weaker (less than 1 kg) than the weakest fishing line (2 kg or 4-5 lbs breaking test) and are thus very easily snapped. In fact, in some instances prisoners now teach other inmates that they should roll over if they receive a CEW discharge, in order to break the wires. The sound pressure level with a good connection is only ~50 dBA but jumps up to ~80 dBA when the connection is broken.

The actual duration of delivered current flow can be estimated by a careful and detailed analysis of sound recordings (crackling implies a lack of connection or intact completed circuit capable of delivering an electrical charge), eyewitness accounts, and probes and wires (longer durations have more effects on the probes and wires). As an example, in the tragic death of the methamphetamine addict, Mr. Robert Heston (Salinas, California) attacked his father and father's home and there were a total of 206 seconds of trigger-pulls on the 5 M26™ CEWs, 6 deployed cartridges, used to attempt to capture and control him. A careful detailed analysis found that the actual duration of current delivery was 5-9 seconds. In another case (unnamed here due to confidentially restrictions) there was a total of 154 seconds of trigger-pull duration from 28 trigger pulls. The actual duration of current delivery was 20 seconds total.

A recent Federal Court ruling included a statement that CEW trigger pull records do not equate to delivered current, quoting the law enforcement defense expert: [240]

> The T[ASER X26 CEW] log shows only device activation; it does not represent that a shock was actually delivered to a body nor does it distinguish between probe deployment and drive stun.

CEW download-implied long-duration exposures usually reflect wire breakage or other circuit interruption and not long durations of current delivery.

T. Creative Contributions

Since the TASER CEW's satisfy all relevant electrical safety standards, it has become difficult for anyone to argue that a CEW electrocuted someone.[84] This has led to some creative arguments for a mechanism of contribution to an ARD.

1. The CEW caused great pain and this led to increased catecholamines, which caused the death.
2. The CEW caused acidosis from muscle contractions, which caused the death.
3. The subject had high catecholamine levels, which made it easier to electrocute.

These will be discussed in sequence.

1. The CEW caused great pain and this led to increased catecholamines, which caused the death.

Catecholamines are the hyper hormones of epinephrine, norepinephrine, and dopamine. It is easy to refute the speculation that the presence of agitation along with the pain of a CEW application would lead to a surge of catecholamines which could contribute to a sudden death. There have been over 1.6 million CEW training applications — all painful — and there have been no deaths. Cardiac arrest is not induced from the pain associated with severe back pain, headaches, broken bones, childbirth, or kidney stones. While emotionally appealing, this speculation is unsupported by any science and runs contrary to extensive experience. People can faint (from other mechanisms then physiologic derangements) from pain but they do not die. Most arrest-related-death subjects are well anesthetized from alcohol, illegal drugs, schizophrenic psychosis, or the endorphins from the struggle. The over 1.6 million CEW trainee officer trainees did not have any anesthesia.

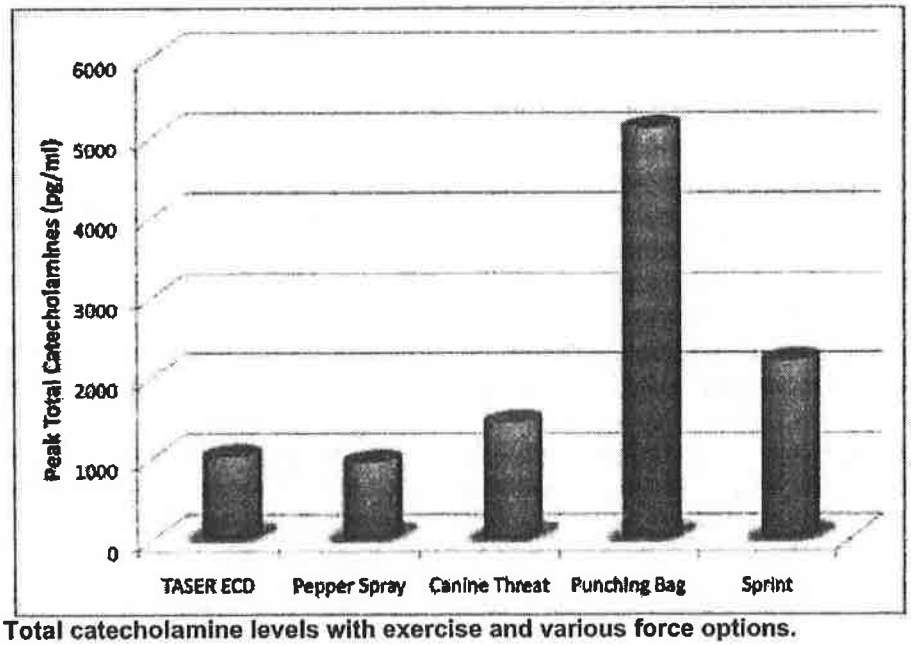

Figure 19. Total catecholamine levels with exercise and various force options.

It is also important to remember that all force options involve the infliction of and experience of pain. That is why some are often referred to as "pain control" or "pain compliance" techniques, weapons, or force options.

A study compared a 15-second TASER X26 CEW *probe-mode* exposure to pepper (oleoresin capsicum) spray, punching a heavy bag, sprinting, and facing a police canine.[37] (The punching and sprinting were meant to simulate the physical exertion of fighting, resisting, or fleeing.) As seen in Figure 19 the greatest increases in catecholamines were obtained from punching and sprinting. The next highest increase was seen with the canine threat. The lowest increase (immediately after the exposure) was with pepper spray while the TASER CEW was 2nd lowest. However, after 3 minutes, the pepper (OC) spray stress began to increase and after 4 minutes post-exposure the X26 CEW had the lowest stress level.

2. The CEW caused acidosis from muscle contractions, which caused the death.

A theory for implicating a TASER ECD in an ARD (arrest-related-death) has been to argue that:

1. the electrical stimulation caused
2. muscle contractions which caused
3. an increase in lactate and CO_2 which was significant enough to cause
4. acidosis which caused death.

This theory appears to be based on swine studies that found acidosis from longer CEW exposures.[183, 184, 241] However, these anesthetized animals had their ventilator turned off during the CEW application and thus had significant breathing compromise. Most importantly, none of the acidotic animals died.

Finally, the acidosis mechanism theory has been refuted by a 30-minute exposure study in which:

1. No swine died with 4 minutes of X26 application.
2. The majority of animals (subjected to a 30-minute exposure) survived.
3. The swine that died actually had ***less*** lactate and CO_2 buildup than those that survived. I.e. acidosis did not cause the deaths. (Anesthetized swine often die unpredictably.)
4. Even at 30 minutes there was no increase in myoglobin thus refuting another common theory of rhabdomyolysis.

The acid buildup in the human is trivial. For example, a 5-second application of an X26 CEW causes a lactate increase in a human that is about 1/6 that of a 20 yard sprint.[242] We can extrapolate and estimate that running from home plate to 1st base (~30 yards) would have the lactate buildup of about 45 seconds of a CEW application.

A study compared a 15-second TASER X26 CEW *probe-mode* exposure to pepper (oleoresin capsicum) spray, punching a heavy bag, sprinting, and facing a police canine.[37] The results are shown in Figure 20.

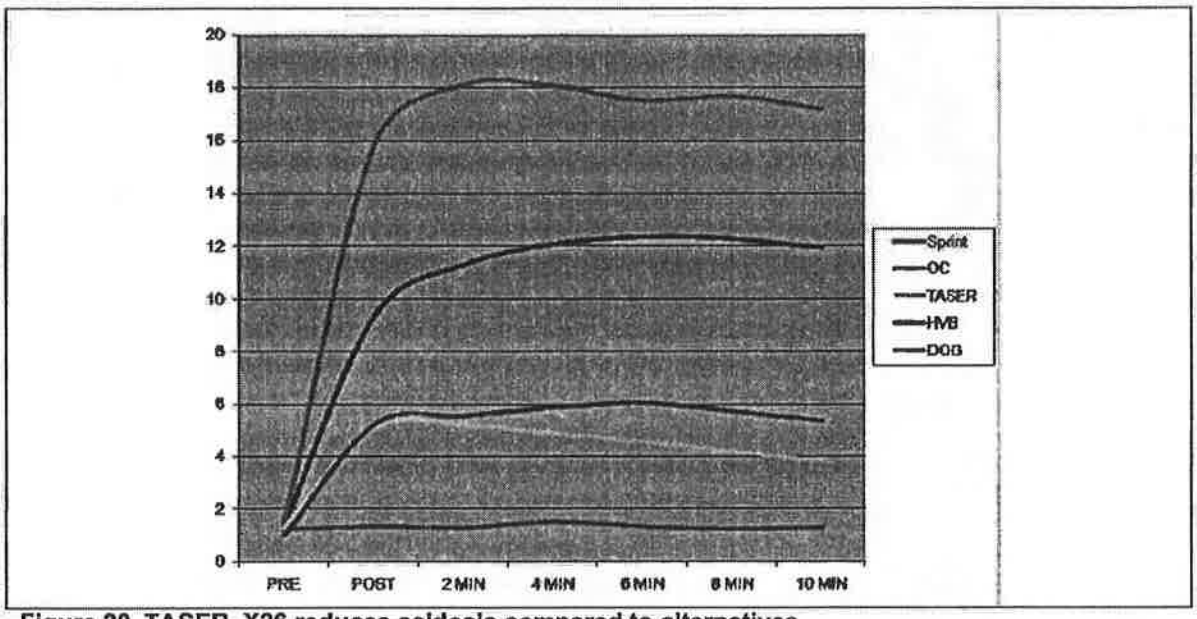

Figure 20. TASER X26 reduces acidosis compared to alternatives.

3. The subject had high catecholamine levels, which made it easier to electrocute.

It is true that high levels of catecholamines (hyper hormones) can lower the VF threshold. This is often seen during electrophysiology studies after a patient was given drugs that increased catecholamine levels.[243] However, as seen in Figure 21 that effect is very temporary lasting only 3-7 minutes.[110] After that time the VF threshold actually *increases* with catecholamine levels.

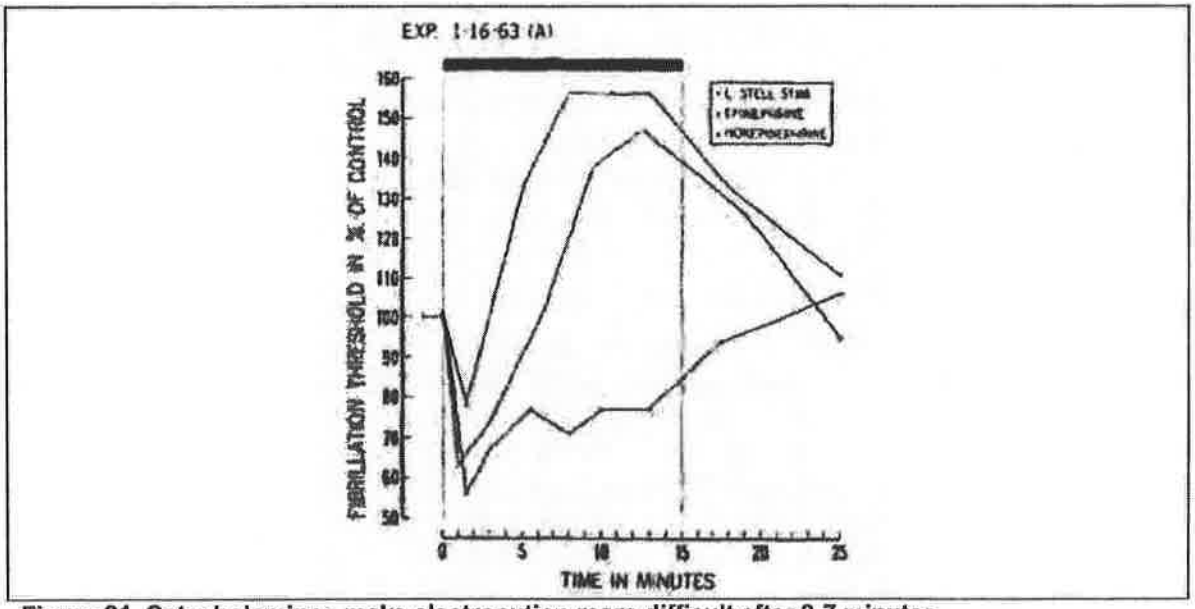

Figure 21. Catecholamines make electrocution more difficult after 3-7 minutes.

The typical excited delirium ARD is excited for much more than 7 minutes by the time law enforcement arrives. Hence, the CEW application is given so much later thus any impact of his catecholamine levels would have been to *increase* the subject's VF threshold. I.e. agitated subjects are actually *harder* to electrocute than someone acting normally.

U. The Risk of Resistance.

Being arrested is a highly emotional event, which is not appreciated by the average law-abiding citizen. The loss of freedom is something most Americans will never experience. This can lead to a supercharged atmosphere, which is highly dangerous.[244] Animals often die from what is broadly defined as "capture myopathy."[245-252]

The exertion of the struggle is far greater than that seen with normal exercise and far greater than that which a typical criminals suspect is accustomed to. This leads to numerous metabolic and electrolytic derangements including elevated levels of lactate, CO_2, potassium, creatine kinase, and myoglobin.[253] An acute stress cardiomyopathy — or takotsubo syndrome — has been suggested as a possibility. [21, 42, 254] The extreme exertion can also unmask a QT prolongation.[255]

Only 1.6% of United States law enforcement interactions involve the use or threats of force, and annually there are about 700,000 interactions in which force is used or threatened.[256] There are approximately 700 arrest-related deaths (ARDs) per year in the USA yielding a mortality rate of about 1:1000 for a law-enforcement interaction associated with force.

Interestingly the overall risk of ARD is similar to the mortality figures related to surgery with general anesthesia or atrial fibrillation ablation, professional or scholastic sports participation, and military training.[257]

Studies covering a total of over 48,000 forceful arrests have found a typical injury reduction of about 65% with CEW adoption.[213] Of the 250,000 annual CEW field uses in the US only 1 in 4000 has been implicated in an ARD. This is consistent with the 2008 Eastman study which found that 5.4% of CEW uses "clearly prevented the use of lethal force by police."[165]

V. The TASER CEW Has Led to Dramatic Reductions in Injury.

Numerous published studies have now clearly demonstrated substantial injury reductions from the use of TASER CEWs compared to alternative control techniques.[211-221]

A partial list of these studies includes:

1. MacDonald which compared the CEW to pepper spray and "physical force."[213]
2. Taylor which compared the CEW to pepper spray, baton strikes, and "hands-on."[212]
3. Mesloh who studied CEW usage in comparison to many control options.[220]
    a. Gentle hold
    b. Handcuff
    c. Leg restraints
    d. Pepper spray
    e. Compliance holds

f. Takedown
g. Empty hand strike
h. FN303/Pepperball
i. Impact weapon
j. Canine

The largest epidemiological study was the 2009 MacDonald study of 24,380 uses of force.[213] This study found that CEW usage dramatically reduced both suspect and officer injury compared to alternative force options. Additional studies demonstrating injury reduction are memorialized in the papers of Taylor (13,983 subjects), Mesloh (n = 4303), Smith (n = 1645), Butler (n = 562), and White (n = 243).[45, 212, 213, 220, 258, 259] On average, the use of the CEW reduces suspect injuries by about 2/3.

To put it another way, the use of alternative control techniques triples (3x) the risk of injury to subjects.

a. The deployment and use of TASER CEWs has been shown to reduce injuries to officers and suspects over other force options, including physical force.
b. The deployment and use of TASER CEWs has been shown to reduce officers' workers' compensation claims for use-of-force and arrest-related injuries.
c. The deployment and use of TASER CEWs has been shown to reduce use-of-force citizen complaints and law enforcement internal affairs complaints against law enforcement officers.[260]
d. The deployment and use of TASER CEWs has resulted in the reduced need to use of deadly lethal force.
e. Rates of injury from TASER CEWs is comparable to, or less than, some collegiate contact and exertion sports.
f. Rates of injury from TASER CEWs is less than several other common law enforcement force options, including, but not limited to: physical force, batons, impact tools, canines, rubber bullets, and bean bags.
g. The deployment and use of TASER CEWs has been found to be a lower risk than most personal force options, including: baton, chemical spray, and pepper spray.
h. TASER CEWs are a safer alternative than other comparable law enforcement force options tools or techniques.
i. TASER CEWs are shown to reduce suspect injuries when compared to physical force options.
j. TASER CEWs are more effective in gaining volitional compliance through presence intimidation than other force options.
k. TASER CEWs have greater accountability features than any other force option.
l. TASER CEWs are the most studied force option available to law enforcement.
m. TASER CEWs are the most effective force option in accomplishing intended effects for U.S. law enforcement.
n. According to peer-reviewed literature, the TASER CEW causes less-severe physiologic and metabolic effects than other force options.
o. According to peer-reviewed literature, the TASER CEW is the safest force option available to law enforcement.